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Range Commanders Council

TELECOMMUNICATIONS AND TIMING GROUP

IRIG STANDARD 210-93

HORACE
PRESENTATION-LEVEL PROTOCOL STANDARD FOR DIGITAL TRANSMISSION OF MONOCHROME TELEVISION IMAGES

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IRIG STANDARD 210-93

HORACE
PRESENTATION-LEVEL PROTOCOL
STANDARD FOR DIGITAL TRANSMISSION OF
MONOCHROME TELEVISION IMAGES

NOVEMBER 1993

Prepared by

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ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

ac	alternating current
A:D	analog to digital
AFB	Air Force Base
AGC	automatic gain control
AMI	alternate mark inversion
anaglyphic	Two views of the same scene from two points displaced slightly in the horizontal direction. When viewed with one image for each eye in the proper order, the observer sees a three-dimensional image as it would be viewed from halfway between the views. An anaglyphic image is not a "true" three-dimensional image as is a hologram, where the perspective changes with the angle at which the hologram is observed.
b&w	black and white
BIT	built-in test
BSSC	bit synchronizer/signal conditioner
CCD	charge-coupled device
CMOS	complementary metal oxide semiconductor
dc	direct current
DPCM	differential pulse-code modulation
ECL	emitter-coupled logic
EIA	Electronic Industries Association
entropy	A measure of the randomness of a system with multiple possible outputs. Maximum entropy exists when the output of a system cannot be predicted, even with knowledge of previous outputs. Minimum entropy is exemplified by the likelihood of death or taxes.
FCC	Federal Communications Commission

ABBREVIATIONS, ACRONYMS, AND DEFINITIONS (CONT'D)

GHz	gigahertz (10^9 Hz)
HORACE	Video compression protocol described in this document.
Hz	hertz
ISDN	integrated switched digital network
kB/s	kilobit per second
kHz	kilohertz
layer	interchangeable with level
level	position in system-level architecture (see reference 21).
line	a portion of the incoming data stream containing one horizontal line of the transmitted picture or one packet of side data. A line begins with the 0000 0000 0001 code and ends before the beginning of the next line's identification code. A line thus defined corresponds to a "frame" in telecommunications and telemetry terminology. A video line may contain padding bits which may be removed without changing the meaning of the line. The choice of the word line is due to the correspondence with a video line on the display; the data lines transmitted may not represent single lines of printed text.
MB/s	megabits per second
Mbits	megabits
MHz	megahertz (10^6 Hz)
MSB	most significant bit
mux	multiplexer

ABBREVIATIONS, ACRONYMS, AND DEFINITIONS (CONT'D)

NAWCWPNS(CL)	Naval Air Warfare Center Weapons Division China Lake
NRZ	non-return to zero
NTSC	National Television Systems Committee
OSG	Optical Systems Group, Range Commanders Council
page	a portion of the incoming data stream which begins at the 0000 0000 0001 identification code for the first line of a picture and ends immediately before the identification code of the next picture. A page contains exactly one picture, contains all data necessary to allow reproduction of that picture, and may contain side data and information regarding the format of side data in the next picture. Finally, a page may contain padding characters which may be removed without changing the data the page contains. The name "page" is used because the page thus defined starts at the top left hand corner of the display as would a page in a printer or typewriter. The picture contained in a single page is a "frame" as defined in motion picture terminology, and a "field" and possibly a "frame" in television technology, if interlace is not used.
presentation level	The level in the communications architecture where the output of the communications system is reformatted into user-specified signals. **Presentation level** is between the **session level** and the ultimate **user level** (see reference 21).
RGB	red, green, blue
session level	The level at which the signal is in its single-user format between the **transport** and **presentation** levels (see reference 21).
SBIR	Small Business Innovative Research

ABBREVIATIONS, ACRONYMS, AND DEFINITIONS (CONT'D)

tail code	a video line may contain additional data following the video information on that line pertaining to color or anaglyphic differences for use by a decoder which can interpret these differences for display. Decoders not equipped to handle tail codes or which cannot handle tail codes in the format defined in the vertical data channel, ignore the tail coded data and display the picture data as received.
TCG	Telecommunications Group, Range Commanders Council
TG	Telemetry Group, Range Commanders Council
TTL	transistor-transistor logic
user level	the original source and ultimate destination of a signal (see reference 21).
UV	color separation vectors (see reference 17)
Vac	volts alternating current
VBI	vertical blanking interval
VHS	video home system
Vpp	volts peak-to-peak
YUV	color separation vectors (see reference 17)

CHAPTER 1

PURPOSE

1.1 This document establishes a single digital television transmission standard with sufficient versatility to meet a large variety of instrumentation needs for DOD test ranges. Within the framework of the standard, the user can specify transmission rate, horizontal and temporal resolutions, and can determine what picture quality is required for any particular use. Additional data, not intended to be part of the displayed picture, can be added between picture fields and between horizontal lines. The decoder requires almost no adjustment when digitized video data and clock signal are fed and can indicate the type of error if errors are detected.

1.2 This standard defines a presentation-level protocol syntax and concerns itself with operation at the user, presentation, and session levels at both ends of the one-way link. The action of the HORACE protocol is unaffected by changes below these levels as long as the received signal at the session level is clocked at a constant rate or has a clock signal associated with it, and the order of data bits is unchanged from those sent. No information is required at the beginning or end of the session, and the presentation level is not normally entered from the start of the session.

1.3 This document is published as a non-exclusive standard to implement the present technique without prejudicing further work in video compression. Future editions will include color and three-dimensional images derived from two closely spaced cameras.

CHAPTER 2

THE HORACE VIDEO COMPRESSION STANDARD

2.1 <u>System Characteristics</u>. The HORACE Video Compression Standard protocol is a digital data format for transmission of National Television Systems Committee (NTSC) television pictures and incidental data via any digital channel. The protocol is defined in binary terms and consists of variable word and frame lengths. For this document, a word may consist of from 1 to 12 bits. Words are grouped together into lines which correspond to lines in the reconstructed picture or lines of binary data. Lines are in turn grouped into pages corresponding to picture fields. The standard telemetry terms, "frame" and "subframe" (reference 14), are not used here in reference to the digital signal to avoid confusion with the word "frame" as it applies to picture images, and because a television frame is normally represented by two pages. A volume consists of any data stream that maintains a constant bit rate. It may contain running changes in quantization intervals, gray-scale resolution, embedded data, and frame/field subsampling rates. (See chapter 3, Features of the HORACE Video Compression Standard).

2.1.1 <u>Video Input And Output</u>. The following paragraphs describe video input and output.

2.1.1.1 <u>Input</u>. The video input shall conform to Electronic Industries Association (EIA) RS-170 (reference 10) and Federal Communications Commission (FCC) standards (reference 9). An exception to these standards is that field repetition rates of 59.4 to 60.6 and horizontal rates of 15,562.5 to 15,938 per second shall be permitted. These tolerances, slightly wider than EIA and FCC standards, allow noninterlaced scanning. This tolerance corresponds to a ± 1 percent variation in vertical-sweep rate from 60 Hz and allows for fields containing 262 or 262.5 lines.

<u>NOTE</u>

There is no requirement to operate with random-interlace input signals, although random-interlace signals can generally be used with field skipping.

2.1.1.2 Output. Sweep rates at the output shall conform to sweep rates at the input within ±1 percent and cannot change more than ±0.3 percent in the duration of a single field sweep. When in variable skip mode, video output sweep rates shall be derived from an internal crystal within ±0.25 percent of nominal or 60 Hz power line lock. The rates shall not change by more than ±0.1 percent during the duration of a single field sweep.

2.1.2 Transmission Format. The digital output from the HORACE encoder and the input expected at the decoder (session level) shall be a continuous digital transmission clocked at a fixed rate. No session header is transmitted as part of this protocol. The decoder can be connected at any time from the beginning of the session. No handshake with the encoder is required, because the decoder will output the first full picture received. The decoder shall be capable of achieving data synchronization upon presentation of the data signal and clock signals. Data at the presentation level is sent as lines. Each line represents an actual line of a picture or a single data packet and starts with a unique line header and identification code.

NOTE

The resulting data stream does not necessarily have ONEs or ZEROs corresponding to fill bits or low picture activity. Consequently, clock stability and low-frequency response on the short term must be sufficient to accommodate such signals. If not, randomization or encryption* must be used to remove DC components and to produce a sufficient number of transitions to maintain bit synchronization.

2.1.2.1 Line Types. Lines transmitted shall be of two types: picture and data.

2.1.2.1 1 Picture Lines. Each picture line transmitted represents a physical line of picture information. Picture line format shall be as described in subparagraph 2.1.9.

2.1.2.1.2 Data Lines. Transmitted data lines contain data packets of fixed or variable length as described in subparagraph 2.1.10.

*See subparagraph 2.4.2 for recommended randomization and encryption systems.

2.1.3 Active Picture Lines. Unless higher vertical resolution modes are engaged (see subparagraph 2.1.19), the number of active picture lines transmitted and displayed per field shall be exactly 240.

2.1.4 Interlace. Unless otherwise specified (see subparagraph 2.1.19), the encoder shall operate in all modes with input signals from interlaced 262.5 lines/field or noninterlaced 262 lines/field. If interlace is present on the input picture, information regarding odd/even shall be sent in the picture format codes. Noninterlaced fields shall be identified by the encoder as odd fields.

2.1.5 Error Handling. The HORACE protocol will perform flawlessly only with an error-free channel. When errors occur, some disruption of the reconstructed picture will result. The amount of disruption will depend on the type and location of the data error. References 11 and 12 discuss error measurements made on actual systems. Essentially, perfect reception results from an error rate at the received session level of $1:10^{-6}$ or lower. Forward error correction at levels below the presentation level may be employed if necessary to achieve this rate. Error identification without correction serves no purpose to the user. The effects of data errors are almost always readily apparent. Disruptions and recovery time are functions of the system and of the decoder design and thus a concern when ordering decoders to this specification.

2.1.5.1 Error Correction Systems. Perfect reception and decoding of a television picture requires a noiseless channel. Because such a channel is only a theoretical ideal, error correction in the channel may be employed external to the system. The effects of the error correction system used at the decoder shall be transparent.

2.1.5.2 Error Recovery. When data error results in a garbled picture or data line, the decoder shall display an error indication and shall immediately begin seeking the start-of-line code for relock. Depending on the type and location of the error, disruption of the output picture and of synchronization shall be minimized. Error recovery for uncorrected errors at the presentation level requires no assistance from lower levels.

2.1.5.3 Clock Slippage. Clock signals are fed to the decoder from external equipment or from a synchronizer card located within the decoder frame. At startup and after any clock slippage, the decoder shall reacquire line synchronization after reception of no more than one valid start-of-line word. Page synchronization will be required after reception of no more than three video lines or one data line. The video output signal shall be correct within less than one page length. The vertical

rate of the video output shall be within ±3 percent at the start of valid data. In addition, the rate shall be within ±1 percent of 3 seconds at the start of synchronized clocks and error-free data.

2.1.5.4 Data Errors. The system will be required to operate in the presence of data errors. These data errors are garbled data presented to the network at the sender's presentation level. Transmission over a noisy single-channel telemetry link is an example. Data errors, which can occur within the picture portion of a line or within synchronization or data transmission intervals, may disturb the rest of the line and cause further disruption. Consequently, any decoder response shall be characterized for its reaction to the error types listed in the following subparagraphs.

2.1.5.4.1 Isolated, Single Bit. An isolated bit is a single bit transmitted in error, that is, a ONE where a ZERO was intended or a ZERO where a ONE was intended. The duration of a single-bit error is exactly one data bit in length with the bits to either side of the error transmitted correctly.

2.1.5.4.2 Isolated, Asynchronous. A noise burst containing only ONEs or ZEROs or a combination of both with transitions not necessarily in synchronization with data transitions, results in a one- or two-bit error.

2.1.5.4.3 Burst Errors. A noise burst containing only ONEs or ZEROs or a combination with transitions is not necessarily in synchronization with data clock. (The results of these burst errors will be different from each other.) The noise burst is of a duration such that two or more bits are affected, although some of the bits received may still be correct.

2.1.6 Vertical Data Channel. Data may be emplaced in bits 61 through 98 and 101 through 238 of the vertical data channel. Bits 61 through 98 are assigned to a time-code transmission coincident with the start of the vertical scan. Bits 101 through 238 can be used when assigned to transmit data that change at the vertical scanning rate or to transmit fixed data such as a source identification number. When any of these data bits are used, bit 59 is transmitted as a ONE. The vertical data channel is entirely separate from the data line transmissions described in subparagraph 2.1.10. Information contained in the vertical data channel is not displayed as part of the picture. It may, however, be fed to a display generator which adds time and mission information to the video image or directs data to another user-level display.

2.1.7 Pixel Interleaving (Stagger). When selected in encoders, alternating lines (line stagger) or fields (field stagger) shall be timed, so the first pixel on the line is delayed by half a

pixel from the "undelayed" condition. When a staggered original is presented to the decoder, the decoder shall display the picture staggered as in the original. This feature is used to measure the horizontal distance more accurately between two objects. This measurement is valid as long as the objects are at least two lines tall in a single field (line stagger) or two lines tall in a single frame and did not move between the two fields in the frame (field stagger). In field stagger, the undelayed field shall be field one; in line stagger, the undelayed lines shall be the odd-numbered ones.

2.1.8 Frame/Field Skipping Option. When specified, the encoder may be provided with a field or frame-and-field skipping capability. When selected, the encoder shall transmit a lower number of frames or fields than are present at the video input. The user shall have the option of selecting whether a complete frame or a single field is transmitted. (Field skipping is recommended when motion is present in the picture. The frame-skip option may not be available on all encoders). This option may be used to provide better resolution in the horizontal and gray scale at a loss of temporal resolution. The display repeats the previous field or frame until a new one has been received and then switches to the new one during vertical blanking. In either case, the frame or field selected for transmission is made up of a single field or frame, not a running composite of the input. Subsampling is either selected or variable.

2.1.8.1 Selected. When this option is chosen, the user may select the number of pictures to be sent. For example, the user elects to send just every fourth picture. The adaptive functions of the encoder are still engaged, so the encoder will transmit the best picture possible for the bit rate in use.

2.1.8.2 Variable. When the variable rate is selected, the encoder transmits the picture with the full selected horizontal resolution and with entropy coding, transmitting a new field or frame whenever the buffer is low enough to handle a complete new one. Variable skipping transmits the best still picture possible, but the temporal rate will vary with picture complexity.

2.1.9 Line Format. Each line shall consist of the 12-bit start-of-line code, a 10-bit format code, fill bits (if present), a fill-terminator bit, fixed- or variable-length pixel codes of a number indicated by the format code, and tail codes (if present).

2.1.9.1 Start-Of-Line Code. The start-of-line code shall be the 12-bit word 000000000001.

NOTE

This pattern cannot occur within a picture line but can exist in a data line and must be constrained in tail codes. When the pattern occurs in a data or picture line, the pattern is ignored by the decoder because of position, since data in the format codes that follow can differentiate the two occurrences. As a consequence of this start-of-line code, systems sensitive to as few as 11 adjacent ZEROs require randomization or encryption at the presentation level or ZERO substitution at the transport level or below.

2.1.9.2 Format Code, Picture Line. The 10-bit format code that follows the start-of-line code shall be defined as described in the following subparagraphs and in table 2-1.

2.1.9.2.1 Bit 1: Static Parameter Subcodes. Format bit 1 varies with its position in the field as specified next. Because the bit stream separated from this bit has one bit per line, it is also referred to as the vertical data channel.

TABLE 2-1. STATIC PARAMETER SUBCODES

Line Number	Meaning		Values
1-3	Start of field (Note 1)		000
4-13	Alignment code (Note 2)		0101010010
14-17	Pixels per line (full resolution)	128	0000
		160	0100
		225	1000
		256	0001
		320	0101
		450	1001
		512	0010
		640	0110
		900	1010
		1024	0011
		1280	0111
		1800	1011
18	Frame/field skip ON (Note 3)		1
19	Skip type is FRAME (Note 3)		1

TABLE 2-1. STATIC PARAMETER SUBCODES (CONT'D)

Line Number	Meaning		Values
20-23	Skip ratio (Note 3)	variable	0001
		2:1	0010
		3:1	0011
		4:1	0100
		:	:
		15:1	1111
		16:1	0000
24	Horizontal interleave ON (Note 4)	1	
25	Interleave type is FIELD (Note 4)	1	
26	Vertical interlace ON (Note 5)		1
27-31	DPCM kernel identification (Note 6)		00000
32-34	Entropy code identification (Note 7)		000
35-36	Buffer status multiplier (bytes/line) (Note 8)	128X	01
		256X	10
		512X	11
		1024X	00
37-41	Encoder buffer capacity (bytes) (Note 9)	8K	00001
		16K	00010
		24K	00011
		:	:
		248K	11111
		256K	00000
42	Data multiplex ON (Note 10)		1
43-52	Multiplex line length (Note 11)	1	0000000000
		2	0000000001
		3	0000000010
		4	0000000011
		:	:
		1023	1111111110
		1024	1111111111
53-58	Field number (modulo 64) (Note 12)		(varies)
59	Data in vertical (Note 13)		0
60	Data in horizontal (Note 14)		0
61-98	Date/time (See subparagraph 2.1.15)		(varies)
99	Tail codes present (Note 15)		1
100	Color/3D indication (Note 16)		X
101-238	Undefined spares (Note 17)		0 (all)
239-240	End of video (Note 18 and subparagraph 2.1.19)		00

NOTES

1. The format data bit in the first three lines of a field shall be ZERO. These bits may be used for error handling.

2. Format data bits 4 through 13 are used to establish synchronization of the vertical data channel.

3. When the frame/field skip format bit 18 is a ONE, fewer than all frames or fields are being sent by the encoder. When format bit 19 is a ONE, frames are being sent; if format bit 19 is a ZERO, fields are being sent. Bits 20 through 23 indicate the ratio of pictures input to pictures sent. When skip ratio is variable, a frame or field is sent at any time the encoder buffer can hold an entire new picture. When frame or field skipping is ON, the decoder repeats the previous picture until the next picture is received, and switches to the new picture during vertical blanking.

4. The interleave function, when engaged, causes the A:D converter to sample selected lines of the video signal at a point midway between the normal sampling points for each pixel. When the line interleave is engaged, alternate lines in each field will have the sampling points delayed on all of the odd lines of the field. When the field interleave is selected, field one of each frame will be sampled in the normal position and field two will be sampled in the delayed mode. Interleaving (when engaged) results in doubling the number of horizontal positions that are sampled in a field or frame. Interleaving improves the horizontal resolution of objects that are at least two lines tall in a given field. Format data bits 24 and 25 are used to inform the decoder of the presence and type of interleaving in use. The decoder uses this information to properly interleave the display as an exact reproduction of the encoded picture. Pixel interleaving is not recommended for input sources derived from pixilated originals.

5. Format data bit 26 is ZERO when the input picture is not interlaced and is ONE with an interlaced source.

6. A differential pulse-code modulation (DPCM) kernel consists of a set of normal DPCM codes, high-level DPCM codes, and two-bit delta DPCM codes. The set defined in subparagraphs 2.1.9.5.1 through 2.1.9.5.3 are identified as kernel 00000. If other kernels are defined, they will carry a different identification.

7. The entropy code identification number defines the variable-length coding scheme used for the transmitted codes. Table 2-2 in subparagraph 2.1.9.5.5 has been assigned the entropy code identification 000. Any other code will carry a different identification number.

8. These bits indicate the multiplier to be used in obtaining the encoder buffer status. The number of lines having bit 7 set to a ONE is multiplied by the value given (128X to 1024X) to obtain the buffer level in bytes.

9. These bits specify the encoder buffer capacity in (8-bit) bytes and are fixed for a given encoder.

10. When this bit is set to a ONE, the encoder should expect at least one data *line at the end of the current page or within* the following page (see subparagraph 2.1.10).

11. When data multiplexing (vertical channel bit 42) is enabled, bits 43 through 52 identify the length of the data packet to be sent within or after the page in which these codes are sent. If variable-length packets are to be sent, these codes should be set to the maximum code length of any packet. The packet header for each data line must contain the actual packet length in the header.

12. The modulo-64 field number is used to identify missing fields resulting from frame or field subsampling. The starting point is arbitrary. Numbered fields are input fields not fields sent.

13. When static parameter bit 59 is a ONE, it indicates that a binary data signal is sent at the edge (normally the left-hand edge) of the picture and is intended to be an attribute of the displayed figure. When this capability is used, horizontal unblanking timing and pulse duration are more critical than when this feature is not used.

14. When static parameter bit 60 is a ONE, it indicates that a binary data signal is sent at a horizontal edge (top or bottom) of the picture and is intended to be an attribute of the displayed figure. When this capability is used, vertical unblanking timing and pulse duration are more critical than when this feature is not used. Encoded data should be confined to lines 24 to 262 counting from onset of vertical blanking. Vertical blanking interval (VBI) signals on lines 10 through 23 in the input signal are not encoded.

15. See subparagraph 2.1.15.

16. When vertical data channel bit 99 is a ZERO, no data may follow the right-end pixel code for any picture line except the padding characters 11111. . . . When vertical data channel bit 99 is a ONE, data is present in the tail code which represents a chromatic difference (for color) or a spatial difference (for anaglyphic signals) which is used to modify the video data transmitted in the current line, and in some cases the previous and following lines, to produce the two or more displays that result. When vertical data channel bit 99 is a ONE, vertical data channel bits 101-110 carry information regarding the nature of the meaning of the tail code separations, and are not undefined spares. When vertical data channel bit 99 is a ZERO, indicating no tail codes are present, vertical data channel bits 101-110 are not constrained and may be assigned by the user for any purpose.

17. Undefined spares shall be transmitted as ZEROs. When uses are defined for these spares, that information will be incorporated into revisions of this document. Users may wish to use these channels to transmit time event markers. Encoders can accept data in these locations in parallel or serial, but parallel or serial must be specified when ordering.

18. The format data bits in the last two picture lines of a field shall be ZERO and may be used in error handling.

2.1.9.2.2 Bit 2: DPCM Type. When format bit 2 is a ZERO, DPCM with entropy coding is engaged for the line. When format bit 2 is a ONE, two-bit DPCM without entropy coding is used for that line.

2.1.9.2.3 Bit 3: Horizontal Subsampling. When format bit 3 is a ZERO, horizontal subsampling shall not be engaged for the line indicated. When format bit 3 is a ONE, horizontal subsampling shall be engaged, and only the odd-numbered samples are sent for that particular line. When a subsampled line is received, the decoder shall display each received pixel twice. Any field may consist of lines that are subsampled and lines that are not. Any line where horizontal subsampling is used has horizontal subsampling engaged for the entire line.

2.1.9.2.4 Bit 4: Fine/Coarse. When format bit 4 is a ZERO, normal delta coding (fine) shall be engaged. When format bit 4 is a ONE, high-level (coarse) delta coding shall be engaged. Both operate with the entropy code described in subparagraph 2.1.9.5. Any field may consist of both types, but only one may be transmitted on any single line.

2.1.9.2.5 Bits 5 And 6: Line Type. Format bits represent the position of a transmitted line in the vertical scan and can be used in conjunction with format bits 8 and 9 for error handling. Format bits 5 and 6 are 00 for the last line of field two (even) and the first three lines of field one (odd). For the next-to-last line of all fields, bits 5 and 6 are 10. For the last line of field one and the first three lines of field two, bits 5 and 6 are 01. For all other lines, bits 5 and 6 are 11. For noninterlaced pictures ("progressive scanning") or even-divisor field subsampled pictures, all fields shall be treated as a field one.

2.1.9.2.6 Bit 7: Encoder Buffer Status. Format bit 7 in conjunction with static parameter bits 35 and 36 (buffer status multiplier) indicates the fullness of the transmit buffer in thermometer style. This information is used by the decoder to establish output picture line rate. The more ONEs transmitted, the fuller the buffer. Buffer status is reported only once per field. This feature is not used in variable frame/field skip mode.

NOTE

The redundancy of the thermometer-style transmission allows departure from that format for error detection and recovery.

2.1.9.2.7 Bits 8 And 9: Modulo-Four Line Counter. Bits 8 and 9 shall provide a modulo-four count of lines transmitted, starting with 00 for the first line of the field and lines five, nine, thirteen . . . (4N + 1); 10 for lines two, six, ten . . . (4N + 2); 01 for lines three, seven, eleven . . . (4N + 3); 11 for lines four, eight, twelve . . . (4N); and N is an integer.

2.1.9.2.8 Bit 10: Spare. No meaning is presently attached to format bit 10 which should be sent as a ZERO. Any assignment of a meaning to format bit 10 will be made in later editions of this document.

2.1.9.3 Fill Bits. The encoder shall transmit 1 to 960 fill bits per line when required to prevent buffer underflow. Fill bits shall be ONEs. Fill-bit group lengths can be constrained to fixed numbers such as multiples of eight bits for error detection and mitigation as described in subparagraphs 2.2.6 and 2.3.7. The use of fill bits or synchronous idle also requires the use of randomization or encryption at the presentation level unless an alternate mark inversion (AMI) signaling format is used. Fill bits are allowed after transmission of picture data and tail codes (if the latter are present) on picture lines, and after the data packet of indicated length is transmitted on a data line. Fill bits shall be ones and may be used in any number.

2.1.9.4 Fill Terminator. The fill terminator signifies the end of the fill-bit interval or indicates that no fill bits were transmitted in a line. The fill terminator is a single ZERO. Since the only valid character to terminate a fill bit transmission at the end of a video or data line is the start character for the next line, no termination character is ended after the fill bits at the end of a line.

2.1.9.5 Pixel Codes. Pixel codes are variable-length or two-bit, fixed-length codes that indicate the change in brightness from the previous pixel or from black at the start of each line. On lines in which entropy coding is used, the L-code for the pixel at the start of the line is defined as a 6, that is, +25 steps, so that the first pixel code transmitted is usually a single ONE. Pixel codes can represent one of three different schemes which may be used adaptively in a single system. The decoder identifies the type of pixel code sent in any given line from the format codes. Only one type of pixel code is used on any line. At least one bit per pixel is present on each line (corresponding to a black line with 256 pixels per line) to 7200 bits (the eight-bit L-code at 900 pixels per line), although pictures resulting in very long lines are uncommon.

2.1.9.5.1 Clipping Levels. When any pixel code is transmitted that would cause the resulting pixel value to be greater than 127 or less than 0, the resulting pixel value shall be clipped at 127 or 0. No out-of-range pixels shall be permitted, and rollover shall not be used.

2.1.9.5.2 Delta Codes, Normal DPCM, Kernel 00000. Eight jump values can be expressed in three bits, each corresponding to brightness value changes between the predictor and the input pixel expressed in the 128-point (seven-bit) range between 0 (blackest black) and 127 (whitest white). For normal DPCM, these values are as follows:

L-Code Number	Jump Value
1	0
2	+ 3
3	- 3
4	+ 8
5	- 8
6	+ 20
7	- 20
8	Maximum Jump

The encoder may be set to produce the L-codes shown at the thresholds used for the decoder at a level halfway between any two adjacent jump values or just above the values shown for the previous code. These differences can be set at the time of encoder manufacture. Setting the jump thresholds low increases resolution and increases the quantity of data resulting from most pictures. Setting the thresholds for the lower sensitivities can reduce noise (coring) in the incoming picture. A higher threshold also reduces picture contrast. When L-code number 8 is called, it indicates a jump of 40 brightness steps in the direction that the largest jump can be taken. As an example, if the previous pixel value were 30, a maximum jump would take pixel value to 70. If previous pixel value were 63, a maximum jump would take pixel value to 103. If previous pixel value were 64 or more, the maximum jump would subtract 40 brightness steps.

NOTE

If the maximum-jump feature is not required by the user, it can be deleted in the encoder only.

2.1.9.5.3 Delta Codes, High-Level (Coarse) DPCM, Kernel 00000. Eight jump values can be expressed in three bits, each corresponding to brightness value changes between the predictor and the input pixel expressed in the 128-point (seven-bit) range between 0 (blackest black) and 127 (whitest white). For high-level (coarse) DPCM, these values are as follows:

L-Code Number	Jump Value
1	0
2	+ 4
3	- 4
4	+ 10
5	- 10
6	+ 25
7	- 25
8	Maximum Jump

The encoder may be set to produce the L-codes shown at the thresholds used for the decoder at a level halfway between any two adjacent jump values or just above the values shown for the previous code. These differences can be set at the time of encoder manufacture. Setting the jump thresholds low increases resolution and increases the quantity of data resulting from most pictures. Setting the thresholds for the lower sensitivities can reduce noise but can also reduce picture contrast. The actual threshold setting for this fallback mode depends on the amount of picture degradation that is considered acceptable for this operating mode. When L-code number 8 is called, it indicates a jump of 50 brightness steps in the direction that the largest jump can be taken. As an example, if the previous pixel value were 30, a maximum jump would take pixel value to 80. If previous pixel value were 63, a maximum jump would take pixel value to 113. If previous pixel value were 64 or more, the maximum jump would subtract 50 brightness steps.

2.1.9.5.4 Delta Codes, Two-Bit DPCM, Kernel 00000. Four jump values can be expressed in two bits, each corresponding to brightness value changes between the predictor and the input pixel expressed in the 128-point (seven-bit) range between 0 (blackest black) and 127 (whitest white). Since entropy coding is not used with the two-bit DPCM mode, the code value is transmitted directly. For two-bit DPCM, these values are as follows:

Code Value	Jump Value
00	- 26
10	- 4
01	+ 26
11	+ 4

2.1.9.5.5 Entropy Code Table, Kernel 000. When either normal or high-level entropy delta coding is engaged, the transmitted code is determined by the previous code value as shown in table 2-2. The "previous" L-code level is shown on the left (rows); the "next" level is shown in columns.

TABLE 2-2. ENTROPY CODE TABLE, KERNEL 000								
	To Next L-Code							
From L-Code↓	1	2	3	4	5	6	7	8
1	1	001	01	00001	0001	0000001	00001	00000001
2	1	01	001	0001	00001	000001	0000001	00000001
3	1	0001	01	00001	001	0000001	000001	00000001
4	001	01	00001	1	000001	0001	0000001	00000001
5	001	00001	01	000001	1	0000001	0001	00000001
6	0001	001	00001	01	000001	1	0000001	00000001
7	001	00001	0001	0000001	01	000001	1	00000001
8	1	001	01	00001	0001	0000001	000001	00000001

2.1.9.6 Idle Transmission. Transmission of an idle signal between pages is permitted. Following the transmission of the last (240th) line of any page (including tail codes and data lines), a continuous string of ONEs may be transmitted, ending with the normal start-of-line header for the first line of the next page. Transmission of the idle signal should only occur when the encoder is operating at full resolution and then only to fill the presentation-level signal to the comm rate selected.

2.1.10 Data Lines. A data line is used to send fixed- or variable-length binary data as side data along with the transmitted picture. Data thus transmitted may or may not be related to the picture content at the user's option. Data lines may be transmitted in unlimited numbers between pages with all systems, and fixed or variable data word lengths (up to a maximum of 1024 data bits in each line) may be transmitted as indicated here. When data lines are transmitted following a picture in a page, the data lines are numbered consecutively above the last picture line. When data lines are transmitted between picture lines within a page, all lines must be of the length described in locations 43-52 of the vertical channel from the previous page or must each contain the length code in that line's header as described in table 2-1 and subparagraph 2.1.10.3.

2.1.10.1 Data Line Identification. Transmission of data packet lengths up to 1024 bits per data line is allowed at the user's option. Each data packet is transmitted as a line beginning with the code 000000000001, followed by the data line format code 1101010110, followed by the fill terminator, and optionally followed by the packet length in binary notation with most

significant bit (MSB) first. Transmission of packet length is not required if all packets are the same length and the length is specified by vertical data channel data bits 43 through 52.

2.1.10.2 Data Lines Present Identification. The presence of data lines in a signal is identified by the presence of a ONE in bit 42 of the static parameter subcodes.

2.1.10.3 Data Packet Length. The length of each data packet transmitted as part of a data line is indicated on lines 43 through 52 of the vertical data channel. If variable-length packets are used, the indication on lines 43 through 52 shows the maximum packet length, and the length of each packet is indicated in its own data line header. The maximum packet length in any case is 1024 bits.

2.1.10.4 Number Of Data Lines. Any number of data lines may be transmitted as long as they are all of the same length. When lines are transmitted between fields (pages), they carry line numbers from 241 up for reference purposes, since 240 picture lines are sent per page. For any given transmission rate, the larger the data lines in length and number, the lower the picture resolution that is sent as a direct consequence of the added data overhead.

2.1.10.5 Dynamic Switching Of Data Lines. The number and length of data lines may be varied dynamically within the constraints of a single data volume. When this dynamic switching is done, the subcodes sent on lines 42 through 52 on a given page are effective on lines 241 and beyond on the following page, not on the page that contains those changes. The use of dynamically switched data lines requires an error-free transmission because certain error-recovery capabilities are negated by this type of use.

2.1.10.6 Data Packet Message Constraints. No constraints are placed on the data contained in a data packet. The data may have long runs of ZEROs or ONEs and may contain synchronization codes for other functions in the presentation level. If randomization or encryption is not used at the presentation level for the entire HORACE data stream, the data (but not the data header) may be randomized. Nothing prevents use of randomization or encryption at both points, but there is no advantage to doing so unless garbled data is anticipated. Double randomization of the data packets reduces the chances of false synchronization in these instances.

2.1.10.7 Data Escape During Active Video Page. When data multiplexing is engaged, as indicated by vertical data code 10 set to ONE, the two-bit coarse full horizontal resolution mode is constrained, and reception of the data line format code 1101010110 identifies the start of a data line. The data line

identification reassignment shall be in effect until the end of a page where vertical data code is set to ZERO. Any number of data lines may be sent between picture lines within a page or between pages. The data line format code serves as an escape sequence to redirect the incoming data stream to a data buffer, and the next video line code escapes the data buffer and returns the pointer to the video buffer at the beginning of the next video line in the page being formed.

2.1.11 Level Extensions. While eight possible brightness level changes are defined for the two entropy-coded modes, the system is not in theory limited to eight levels. Extensions to this system can be made to define more than eight possible brightness changes, thus lengthening the entropy code tables.

2.1.12 Tail Codes. Additional picture-related data may be transmitted at the end of each picture line after the identified number of pixel values is transmitted. This tail-code signal may be used to transmit one or two color-separation signals or anaglyphic three-dimensional picture separation material. Standards for these modes will be published in subsequent revisions of this document. Transmission of tail codes is transparent to a decoder not designed to accept them, and a decoder designed to receive tail codes and modify the output picture accordingly will operate when tail codes are not present. Consequently, a color picture received on a black-and-white decoder will reproduce a normal black-and-white picture. The presence of tail codes is indicated by a ONE in bit 99 of the vertical channel. If bit 99 is a ZERO, tail codes should not be present. If tail codes are present as indicated by bit 99, the status of vertical channel bit 100 identifies the meaning of the data sent. Vertical channel information can be used by the decoder in error handling.

2.1.13 Data In Picture. In accordance with reference 15, data may be added at the left-hand edge of the transmitted picture. The data appears as white dots where a ONE is sent. Duration of these pulses is 3 ± 1 microseconds, and the picture line on which it starts has a tolerance of ± 2 lines. These data are transmitted as part of the picture and may be recovered from the decoded picture as in a completely analog system. The start of a ONE in the system is indicated by a maximum jump. The start of a ZERO is indicated by L-code 1, 2, or 4. Onset of the data may be adjusted on the data encoder prior to use. This use is transparent to the system as long as the unblanking periods are compatible between the source and the encoder.

2.1.14 Pixel Stagger. Pixel stagger or interleave is defined as an operating mode where alternating lines or fields have pixels delayed by half a pixel interval. Objects in the picture tall enough to cross two lines in a single field (line interleave) or in a frame (field interleave) can be located to half-pixel accuracy. Accordingly, pixel stagger effectively doubles

resolution of such measurements. A staggered transmission is identified by bits 24 and 25 of the vertical static parameter subcode channel.

2.1.15 Time And Date Code Transmission. Time code information is coded as vertical channel data bits 61 through 98 and represent the time at which the page being transmitted was taken, not the time at which the picture is sent. If a shuttered camera is used to produce the original image, the indicated time is the instant of actual exposure. Since the duration of the shutter opening is on the order of 100 microseconds to several milliseconds, resolution of the time stamp is provided to the nearest 100 μs. The time indicated should correspond to the instant of opening of the shutter, or if a strobe light is used, indicated time should correspond to the time at which the strobe is triggered. In either case, starting times are typically more accurately known than the "center of the exposure" and should be used for timing transmissions.

The standard meanings of the time codes are shown in table 2-3.

TABLE 2-3. VERTICAL CHANNEL DATA BIT TIME CODE

61--64	0 for local or mission time, 1 for GMT/ZULU
62--66	hours (maximum count=23)
67--72	binary minutes (maximum valid count=59)
73--78	binary seconds (maximum valid count=59)
79--82	BCD hundreds of milliseconds
83--86	BCD tens of milliseconds
87--90	BCD milliseconds
91--94	BCD 100 μseconds
95--98	BCD 10 μseconds

NOTE

Within each cell, the most-significant bit is expressed first. Hence, a received 0101 would be interpreted as the decimal number 5.

When an SMPTE[1] time-code source is used, data resolution is limited to seconds and "frame numbers" assigned to complete frames in each second, usually 30 but sometimes 29, and starting with the number one in either case. Since the SMPTE time code is used to identify frame numbers for editing purposes, there is no exact correspondence between the number assigned and the exact timing of the exposure; hence, SMPTE-encoded signals are accurate at best to about ±33 milliseconds. If SMPTE timing is used as a source, the "frame numbers" are carried on data bits 79-82 for tens of "frames" and bits 83-86 for ones of "frames"[2], to which the numbers generated most nearly correspond. To identify the use of SMPTE code, bits 95-98 are set to 1111, a condition that could not occur with use of IRIG timing.

2.1.16 Vertical Channel Spares. Bits 101 through 238 of the vertical data channel may be used for fixed data such as the system identification or data that changes from field to field. Since data lines are provided with greater capacity, this capability is undefined and may be used if desired. Unless provisions are made in the decoder to display these data, they will be ignored by the decoder.

2.1.17 Pixels Per Line. The user shall select the number of pixels per line from the following choices: 128, 160, 225, 256, 320, 450, 512, 640, 900, 1024, 1280, and 1800. Not all choices may be present on any given encoder. The choice is further constrained by the frame/field skipping ratio and output bit rate. Decoders, unless made for specific uses, should operate with all choices.

2.1.18 Adaptive Priorities. When a system encounters a picture of complexity[3], the buffer tends to fill for a period of one page or more. The encoder shall adapt by switching to a lower

[1]The Society of Motion Pictures and Television Engineers (SMPTE) defines a time code often carried on a 1000 Hz carrier with a superficial resemblance to the IRIG B format, carried in the vertical blanking interval, or on a side channel with a video signal. While the SMPTE format appears to have millisecond resolution, it does not necessarily since, among other differences, the 1 kHz carrier frequency is only approximate.

[2]The word "frame" is placed in quotes here to indicate that the word has several meanings determined by context. In this document, a video "frame" is represented by the picture information in one page if the signal is noninterlaced (progressive) and by two if interlace is used.

[3]"Complexity" in a system such as HORACE results from an abrupt or a large number of contrast changes along the horizontal lines of the picture.

resolution mode on randomly selected picture lines distributed throughout the picture. When the buffer tends to empty for a period of one page, fallback modes shall be disengaged until full resolution on all lines is produced, followed by the addition of fill bits as required. The recommended order for fallback modes is from normal to high-level, to horizontal subsampling, to two-bit mode without entropy coding. These priorities may be changed in encoders made for specific purposes. Since the decoder determines the mode used to transmit any line, the order of priorities and the order of lines switched are not specified by this protocol and may vary for different uses.

2.1.19 Extended Vertical Resolution and Progressive Scanning. The HORACE transmission protocol can be used to transmit progressive-scanned video images, high-definition video images ["HDTV"] in monochrome, anaglyphic 3-D, or color, interlaced or progressive high line rate images as defined in RCC document 452-86, *Video Standards and Formats,* and high-resolution computer display images. Pictures in these categories represent an extension to the 240-line limit used for NTSC picture transmissions. In all instances, the number of lines per page exceeds the previous 240-line maximum, and data necessary to allow decoding of the high-resolution images permitted by this extension are transmitted in the vertical data channel in picture lines 241-256. Thus, any extended format must contain at least 256 lines in each picture. All pages in a single session (file) must contain the same number of video lines. For any session, the number of video lines is fixed. In any case, the last two picture lines in any transmission are identified by unique line codes, so if picture lines 239 and 240 are identified, the standard (default) 240-line picture with 4:3 aspect ratio is assumed. The last two picture lines of the page are identified in subparagraph 2.1.9.2.5.

Vertical data channel codes for extended vertical resolution are defined as shown in table 2-4.

TABLE 2-4. EXTENDED VERTICAL RESOLUTION LINE CODE DEFINITIONS

Video Line	Meaning
241--242	00=progressive 01=interlaced 10=vertical and horizontal interlace (MUSE) 11=user-defined scanning and interlace
243--244	00=4:3 aspect ratio (default---NTSC, PAL/SECAM, RCC/OSG-452 01=16:9 aspect ratio (HDTV) 10=1:1 aspect ratio (square---Landsat images) 11=user-defined
245--256	>260: number of lines per page (binary, MSB first) <259: undefined, use line ID numbers for count

Vertical data channels in the range above number 256 are user defined.

2.2 Encoder Characteristics. Encoders can take any size and shape as long as they conform to the HORACE interchange protocol specified in paragraph 2.1. Encoders need not be capable of all output data rates nor of all resolutions and, in some uses, need not have all operating modes. Reference 5 can be used to describe black-and-white encoders compatible with the standard in a variety of package styles, power supply types, environmental ranges, and logic families and bit rates from 45 Mbits/second down. Other specifications may be used as long as the requirements of paragraph 2.1 or the desired subset are observed. Subparagraph 2.2.6 provides a listing of the variables that need to be considered when ordering an encoder to operate this protocol. (See chapter 5 for photographs of encoders built by various manufacturers for different applications).

2.2.1 Output Levels. The encoder produces an output at standard transistor-transistor logic (TTL) levels. In addition, the encoder can be specified to have sufficient drive to operate into 50- or 75-ohm coaxial lines. When the clock signal is generated internally, it also operates at TTL levels with the rising edge of the clock coincident with or up to 90 electrical degrees after the rising edge of the data.

2.2.1.1 Data Code. The clock duty cycle is 50 percent with 30 to 70 percent allowed, and the data duty cycle is 100 percent (referred to as a non-return-to-zero (NRZ) format (see reference 15)). If the data output from a specific encoder is specified for operation into a 50- or 75-ohm coaxial line, the clock is also required to do so. When an external clock signal is applied, it should also be at TTL levels with one unit load (3000 ohms to the +5-volt rail) maximum.

2.2.1.2 Auxiliary Output Interfaces. Other output interfaces may be required for use with other equipment. When specified, a three-level output with alternating polarity on the ONE level and 6 Vpp amplitude may be provided. The clock level, if fed from the channel bank, should be at TTL levels. A phase adjustment is provided to synchronize data with the requirements of the channel bank. The output duty cycle of the ONEs can be specified as either 50 or 100 percent.

2.2.2 Input Characteristics. Standard video and data inputs are described in the following subparagraphs.

2.2.2.1 Video Signal. The input video signal fed to the encoder should be a standard RS-170 black-and-white signal with 1 Vpp amplitude intended for termination with 75 ohms or as otherwise specified for a given requirement. The video signal may be either ac- or dc-coupled. Most encoder implementations have

automatic gain control (AGC) to accommodate voltage variations from 0.5 to 2 Vpp, and most have some capability of rejecting common-mode noise (ac hum) or dc offsets.

2.2.2.1.1 Polarity. Synchronization pulses should be of negative polarity assuming that the shield is grounded. Some implementations (for example, NWC 2421, Type I) allow feeding with a shielded twisted pair. In this case, the cable shield may be connected to the encoder case or may be left floating.

2.2.2.1.2 Interlace. The encoder can operate with NTSC signals with 525-lines-per-frame NTSC signals and two 262.5-line frames or noninterlaced (non-NTSC) signals consisting of fields with 262 or 263 line fields. Where the horizontal and vertical sweep oscillators are both free-running, random interlaced pictures may produce unusual results depending in part on how the decoder handles interlace.

2.2.2.1.3 Sweep-Rate Tolerances. The encoder accepts sweep-rate tolerances of at least ±1 percent on vertical rate at 60 Hz and the horizontal rates associated with the permitted variation in the vertical rate with from 262 to 263 lines per field.

2.2.2.1.4 Color Burst. Color burst should not be present on a signal fed to a black-and-white encoder. With color encoders, burst should be present only on composite-input types.

2.2.2.2 Data Inputs. High-speed data is entered on data lines, while field-rate data is typically entered in the vertical channel.

2.2.2.2.1 Data Lines. Data inputs for data lines are accepted at TTL levels with one unit load maximum at the data port. When data are called for, the clock/strobe line goes high once for each bit to be input. The input should be from some sort of serial-out register provided by the user. The number and maximum length of data lines are fixed by the manufacturer. If the number of bits in the data lines is allowed to vary because of register "fullness," additional input lines must be provided when manufactured. Data line length changes are sent as indicated in subparagraph 2.1.9.2.1, note 11.

2.2.2.2.2 Vertical Channel Data Inputs. Vertical channel timing and spare inputs are configured at the time of the manufacture.

2.2.2.2.2.1 Timing Inputs. Parallel inputs to the vertical input channel bits 61 through 98, if used, are provided at the time of manufacture. Timing inputs shall, at most, provide a single TTL unit load and be latched for a given field (page) immediately prior to transmission of picture line 1.

2.2.2.2.2.2 Undefined Spares. Fixed patterns in the undefined spares positions (bits 101 through 238) are specified at time of manufacture. Variable inputs shall be loaded in parallel, provide a single TTL unit load, and be latched for any field (page) immediately prior to transmission of picture line 1.

2.2.3 Status Indicators. If the two systems are level compatible, normal operation of the encoder/decoder system is best verified by encoder operation with a known input picture signal into a decoder by direct connection of the data and clock lines. For rack-mounted encoders, status indicators can be provided to indicate the status of certain internal circuits not otherwise easily verified. Video outputs can be provided to drive a monitor (video display or waveform monitor) with the picture produced by the encoder's predictor. For smaller encoders, a go/no-go indication can be supplied at logic levels to a connector pin. While not a foolproof indication, such a signal can at least demonstrate a certain degree of confidence that the encoder is operating properly. In any system where operator access is possible, a go/no-go built-in test (BIT) at each card in the encoder is recommended. Other convenient indicators for rack-mounted, repairable encoders are described next.

2.2.3.1 Go/No-Go Status. An all-purpose indicator, similar to a car's idiot lights, signals with a light that power is present, (or a digital ONE on nonrepairable units) that a video input is present, and that an output is being produced. Since the indicator is not all-inclusive, the "go" indication might be present when the unit is malfunctioning but will never indicate "no-go" when the unit is functioning. This function need not be present if the indicators listed next are supplied.

2.2.3.2 Power Indicator. The power indicator is illuminated when the encoder is connected to external power and is turned on. A lighted on/off switch is suggested.

2.2.3.3 Input Present. The indicator is lit when the encoder has at its input a signal of sufficient voltage and a frequency near enough to the horizontal sweep rate for the AGC and sync detector to be within range.

2.2.3.4 Buffer Status. A meter or thermometer light display shows the fullness of the data buffer. Unless variable frame/field skipping is engaged, the buffer status should hover near half full on the average and never over- or underflow in normal operation. In variable skip mode, the action will show how imminent the next picture capture is.

2.2.3.5 Test Pattern. To verify link functions, encoders can be provided with a built-in test pattern that can be sent without a video signal connected to the encoder input.

2.2.4 Clock Rates. Individual encoders need not span the entire clock rates from below 9600 bits/second to over 50 Mbits/second. The maximum data rate specified has a direct bearing on size, cost, and power consumption. Consequently, encoders are normally specified for a specific clock-rate frequency range and may be used with internal or external clocking over that range. The number of pixels per line and frame/field skipping must be selected in such a way as to produce an adequate picture at the data rate used.

2.2.4.1 Internal Clock. Internal clock signals at one or more rates within the range over which the encoder is specified are available for strapping into the encoder and may be bridged by the user to operate other equipment. The output clock is normally specified at TTL levels.

2.2.4.2 External Clock. An external TTL-compatible clock over the range specified for an individual encoder may be used instead of the internal clocks in the encoder. The encoder normally responds to the rising edge of the clock signal. If the external clock is at some level other than TTL (as might be the case at a telephone hierarchy port), translation is accomplished by the card that translates the encoder output to the telephone interface levels.

2.2.5 User-Selectable Options. For a given bit rate, the user must select the number of pixels per line and the frame/field skipping to produce the desired picture quality.

2.2.5.1 Pixels Per Line. The encoder has one or more choices for the number of pixels per line in the highest-resolution mode. When the encoder approaches overload because of picture complexity, the horizontal resolution is cut in half on selected lines. From the available numbers, the user should select a number that will provide the desired picture quality with a representative picture. A higher number can result in greater use of the lower resolution modes or fewer pictures transmitted per second if variable skipping is used. In general, the highest number that produces a picture without undesired lower-resolution modes on complex pictures should be selected. A lower resolution for a given bit rate is not easier to transmit as far as error performance is concerned.

2.2.5.2 Picture Skipping. If not all pictures are sent, two methods are available to determine which pictures are sent.

2.2.5.2.1 Selected. If field skipping is engaged, picture quality (for example, number of pixels per line or use of fallback modes) is increased at a loss of temporal resolution, which may be preferable in some instances. Frame rather than field skipping preserves all vertical detail on interlaced originals but blurs any object in motion. The various skip modes

are options available c ~ome encoders and may transmit every other to every sixteenL. .ield or frame as selected.

2.2.5.2.2 Variable. If variable field skipping is engaged, picture quality will be at the encoders resolution mode selected by the user with no fallback modes used. Pictures will be sent as often as possible for the resolution selected. Setting a lower number of pixels per line will increase the number of pictures (pages) sent.

NOTE

If fewer pixels are selected, each pixel tends to be less correlated with its neighbors than when a higher number is used. The page transmission rate is not exactly inversely proportional to the number of pixels selected per line.

2.2.6 Ordering Data. When ordering or describing an encoder to this standard, the following variables must be specified. Typical characteristics are shown where applicable.

2.2.6.1 Inputs. Video and optional data signals are accepted as inputs to the system.

2.2.6.1.1 Video. Typical video input is 75-ohm terminated, differential with sync negative. Voltage level is normally 1.0 Vpp, but an AGC may be specified to operate, for example, over 0.5 to 2 Vpp. If an AGC is specified, it should operate independently of sync level. Some systems may use a higher impedance. Common impedances are 93 or 124 ohms. Some requirements may specify a high input impedance with external termination provided. Polarity of the video signal is usually such that the sync signal is the most negative voltage with respect to the center pin or "plus" input on the encoder. The signal must, in all cases, be NTSC video and conform to FCC standards for black-and-white television, except that noninterlaced scanning is permitted. Color burst is not permitted unless otherwise specified.

2.2.6.1.2 Data. Input data formats for the horizontal and vertical data may be configured by the user.

2.2.6.1.2.1 Horizontal Data Lines. Horizontal data lines are optional and are as described in subparagraph 2.1.10.

2.2.6.1.2.1.1 Number Of Lines. The number of lines to be used per field must be specified. The number is typically between 0 (no data lines) and 10. All data lines must be of the same length.

2.2.6.1.2.1.2 Line Length. Line length for data lines must be specified. Maximum length is 1024 bits, and minimum length is 1 bit.

2.2.6.1.2.1.3 Variable Line Length. If variable line length is desired, it must be specified when the encoder is ordered. This feature may be useful if the fed data are not synchronized to the picture or entropy coded.

2.2.6.1.2.1.4 Data Line Location. Data lines may be transmitted between fields in which case the lines for page count purposes are numbered 241, 242 . . . or between picture lines in which case they are unnumbered.

2.2.6.1.2.1.5 Compatibility. Data lines received by a decoder not equipped to handle them shall be ignored and the output picture displayed in the normal manner.

2.2.6.1.2.2 Vertical Channel Data. User-fed vertical data channel inputs are of two types.

2.2.6.1.2.2.1 Time Code Lines. If time code is sent (see subparagraph 2.1.9.2.1, note 12), encoders that can provide parallel access to vertical channel bits 61 through 98 should be ordered.

2.2.6.1.2.2.2 Vertical Channel Spares. If vertical channel spares one each in lines 101 through 238 are used (see subparagraph 2.1.9.2.1, note 18), access to the desired bits must be specified.

2.2.6.2 Output. The HORACE encoder produces a single multiplexed output representing the input picture and optional data signals.

2.2.6.2.1 Communications Bit Rate. The maximum desired operating bit rate must be specified at the time of manufacture. Encoders are capable of operating at any bit rate below this maximum, but practicality limits the lower rates. At 9600 bits/second, a picture would take about 15 seconds to transmit at typical resolutions. The maximum bit rate is limited by system design and the logic family used. Actual bit rate selection is governed by the user requirements and by the limitations of the channel as described in chapter 4.

NOTE

In actual operation, bit rate is user-selected; however, the best picture quality and network compatibility are obtained by operating synchronously at the maximum rate allowed for the channel.

2.2.6.2.2 Data Clock Sources. Encoders may be provided with one or more internal clock oscillators or may be driven by an external source at any bit rate up to the maximum specified for that unit. If an external source is to be used, logic voltages, impedance, and phase must be specified at the time of order. Examples are TTL voltages, 3000 input impedance referenced to the 5 V supply (one unit load), and output edge coincident with the rising clock edge (0-degree phase).

2.2.6.2.3 Output Format. Output formats other than TTL may be specified. Typical alternatives are alternate-mark inversion (AMI) and push-pull (RS-422).

2.2.6.3 Settings. Internal controls may be factory fixed, switchable, or changed by jumpers on cards or connectors as specified.

2.2.6.3.1 Pixels Per Line. The number of pixels per line is user defined, may take any value shown in subparagraph 2.1.17, and is selected by setting vertical data channel bits 14 through 17 Typically, encoders have several choices related by simples ratio such as 512, 256, and 128 pixels per line.

2.2.6.3.2 Adaptive Priority. If adaptive priority is other than as shown in subparagraph 2.1.18, the desired priority tree should be stated.

2.2.6.3.3 Frame/Field Skipping Options. If frame or field skipping is desired, it must be specified at the time of ordering. Field skipping is normally preferred over frame skipping. The type of skipping (fixed or variable) must be specified. If fixed skipping is desired, the ratios from 2 to 16 must be specified; 2, 3, 4, and 8 are the most common.

2.2.6.3.4 Fill-Word Length Constraints. If fill-word length constraints permitted under subparagraph 2.1.9.3 are desired, each should be specified. Multiples of 16 bits are suggested.

2.2.6.3.5 Hunting. The term "hunting" refers to over- and undershoot on data fallback modes because of changes in picture complexity from one picture to the next and from the top to the bottom of the picture. If an input picture is sent with no compression when compression is needed to keep from overfilling

the transmit buffer, subsequent pictures must be transmitted at lower resolution than otherwise possible because of servo overshoot. Conversely, if a fallback mode is used and picture complexity is lower than expected, fill bits will be added when a higher resolution picture could be transmitted with no fill. Pictures of a continuous event, even pictures containing elements of rapid motion, often vary little from one to the next in terms of complexity. Complexity in a single picture can vary considerably from top to bottom. Adaptation speed is bounded by the two considerations described next.

2.2.6.3.5.1 Static. Adaptive priority shall be such that the number of output bits produced by an unchanging picture differ by less than ±20 percent between the first two logic pages at any compression and less than ±1 percent between the 10th and 11th pages.

2.2.6.3.5.2 Dynamic. Adaptive priority shall be the number of bits produced by a noise picture input (gaussian noise with clean sync) and shall be within ±10 percent of each other.

2.2.6.4 Operating Power. Rack-mounted encoders typically operate on 105 to 140 Vac, 50 to 440 Hz. They may be specified for other ac systems. The dc operation from -24 or -48 Vdc nominal buses can be provided for communication system use. Vehicular systems typically operate on +24 to +32 Vdc or a combination of ±12 and +5 Vdc. Systems operating at 20 Mbit/second maximum rate should require no more than 50 watts. Systems at 10 Mbit/second should require no more than 25 watts for operation exclusive of line-handshaking equipment.

2.2.6.5 Physical Dimensions. Encoders can be made in standard 19-inch racks or in smaller sealed units for vehicular systems. Rack-mounted systems are usually 5 1/4 inches tall and can be made smaller if required. Space is available in the rack frame for a line adaptor card or encryptor.

2.2.6.6 Environmental Conditions. Rack-mount encoders can operate over a temperature range of 0 to 50 °C or higher or as specified. Vehicular encoders are typically specified for a range of -40 to +71 °C or as otherwise specified. Vibration protection requirements for rack-mounted units may include transportation shock, while sand and dust protection requirements may be appropriate for some uses.

2.2.6.7 Repair And Maintenance. Requirements for operating manuals as well as mechanical and electrical drawings if desired, should be made when ordered. Rack-mounted encoders are most easily repaired or diagnosed by board-swapping techniques and diagnostics built into the system software. Smaller units are not field repairable and must be sent to the manufacturer for repair.

2.3 Decoder Characteristics. The standard defined in paragraph 2.1 does not specify a particular package style for the decoder. Typical decoders are rack-mounted units intended for inside use. Encoders, on the other hand, can be used in various situations such as outside, as a portable, or in aircraft. Because ground-station decoders are used with a variety of different encoders, decoders are normally capable of operating with the highest bit rates expected for any encoder. Decoders made in accordance with reference 3 operate in complete conformance with the HORACE protocol defined here. They produce a black-and-white picture with tail codes ignored, that is, from a color or anaglyphic original. In addition, the decoders detect any output data lines present in the input signal at data rates from 21 Mbits/second down to below 9600 bits/second (see subparagraph 2.3.2). When not specifically part of the requirements, characteristics c. the decoder are identified as optional or recommended.

2.3.1 Operation. The decoder shall operate and produce an NTSC-compatible picture when fed data and zero-degree clock signals without any internal or external adjustment. Lights and indicators shall show normal and abnormal operation (see subparagraph 2.3.5).

2.3.1.1 Input Characteristics. The decoder operates when fed data and clock signals.

2.3.1.1.1 Voltage. Clock and data signals shall be at TTL levels. For other levels or transmission formats, a bit synchronizer/signal conditioner (BSSC) or line adapter card (see subparagraph 2.3.1.2) shall be used.

2.3.1.1.2 Impedance. Input impedance at the TTL clock and data ports shall be 75 ohms produced by a resistor located near the inputs. When this resistor is removed, the input impedance shall be as a single TTL unit load of 3000 ohms pullup or less.

2.3.1.1.3 Polarity. Data polarity at the decoder input shall be noninverted from the encoder output polarity.

2.3.1.1.4 Clock Phase And Timing. The decoder shall operate with a rising clock edge (measured at the 50 percent point) coincident with and up to 90° following the onset (rising or falling edge) of data.

2.3.1.2 Optional Plug-In Cards. Provisions shall be made on the decoder to allow use of plug-in cards to facilitate certain additional uses or interfaces on the decoder. In reference 3 decoder specification, plug-in cards are of the standard 5 1/4-inch Eurocard format using at least the standard pins for 5 V and $\pm$12 V power and grounds, although other decoders may take

different forms. The functions described below may also be provided by separate boxes connected to the decoder inputs or outputs or both.

2.3.1.2.1 Bit-Synchronization Card. A bit-synchronization card accepts a binary digital signal with arbitrary (specified) voltage, impedance, and polarity characteristics and produces the TTL level data and clock signals required by the decoder. Bit synchronizers have limited, possibly fixed, clock rates or clock-rate ranges.

2.3.1.2.2 Decryptor Card. If the incoming signal is encrypted at the presentation level at the source, decryption at the presentation level is required. A typical encrypt/decrypt system is based on the KGV-68 KUTA-class device. This device is a hybrid package small enough to be mounted with all its TEMPEST support circuitry on a card within the decoder itself. The class and key codes of the sending and receiving cryptographic hardware must be the same for operation. An external decryptor, such as the rack-mount KGR-66, may also be used for decoding encrypted transmissions. Use of encryption devices may limit the upper bit rate otherwise attainable with the decoder.

2.3.1.2.3 Line-Interface Card. A line-interface card may be acceptable instead of the bit synchronizer in instances where the decoder input consists of data and a separate clock line. The card may also be utilized if conversion is from three-level logic such as AMI to the TTL voltages used at the decoder inputs. A line-interface card is less complex than a bit-synchronizer card and is preferred whenever possible.

2.3.1.2.4 Data-Line Card. The decoder frame shall provide docking and power for a card that receives the serial data sent in data lines. Such lines are present at the decoder input and reformat the data received into a format compatible with that data's end use.

2.3.1.2.5 Color Card. The decoder card cage shall provide docking, power, analog video interfaces, and tail-code signals, when color transmission is present at the input, for decoding color separations intended to be part of the reconstructed picture. When this card is not present, a color signal shall be rendered at the decoder output as a black-and-white video signal.

2.3.1.2.6 Anaglyphic Separation Card. The decoder card cage shall provide docking, power, analog video interfaces, and tail-code signals when three-dimensional images are transmitted in accordance with this standard. When this card is not present, a three-dimensional signal shall be rendered at the output as a black-and-white video signal.

2.3.1.2.7 Vertical Channel Data Card. The decoder card cage shall provide docking, power, and digital interfaces to allow capturing and distributing of vertical channel signals when such signals are present. When such signals are present and this card is not in place, no degradation of the video or of the data line outputs shall occur.

2.3.2 Operating Bit Rates. Any decoder shall have a specified maximum operating data rate. No minimum data rate need be specified, but data rates have a lower limit because of practicality. Any decoder shall operate at any rate up to and including the maximum rate when a clock signal of appropriate frequency and phase is presented to it.

2.3.3 Pixels Per Line. The decoder shall respond to signals with 128, 160, 225, 256, 320, 450, 512, 640, 900, 1024, 1280, and 1800 pixels per line and adjust automatically to display those resolutions received. Decoders with maximum input bit rates below 20 mb/s are not required to operate with resolutions beyond 640 pixels per line. Maximum resolution is specified at time of manufacture.

2.3.4 Interlace. Input signals containing alternating field information (see subparagraph 2.1.9.2.1, note 5) shall be reproduced with interlace in the correct order. Signals containing one field only shall be reproduced without interlace or by replication on alternating vertical sweeps. Line interpolation shall not be used.

2.3.5 Status Indicators. With HORACE protocol, status indicators can be provided on the decoder to show proper operation and operation modes when an input signal is present. Suggested indicators for a decoder are described next.

2.3.5.1 Input Present. The input present indicator is a green light that signals the presence of both ONEs and ZEROs on the decoder input. The light will not operate (or stay lit) with an open or shorted input.

2.3.5.2 Input Clock Present. The input clock present indicator is a green light that signals the presence of both ONEs and ZEROs on the decoder input.

2.3.5.3 Encoder Buffer Status. The decoder shall display the status of the encoder buffer on a meter or set of LEDs including indications of over- and underflow. The decoder shall indicate that an error in reading encoder buffer status has occurred for any field or page.

2.3.5.4 Decoder Buffer Status. The decoder shall display the status of its internal decoding buffer on a meter or set of LEDs including indications of over- and underflow.

2.3.5.5 Buffer Status Mismatch. The decoder shall indicate a mismatch between buffer status in the encoder and decoder for operating modes in which buffer mismatch is an error.

2.3.6 Environmental Conditions. Decoders are normally intended for rack-mounted applications in an indoor, static, temperature-controlled, generally manned environment. Nothing in this document prevents manufacture of smaller environmental decoders if a need exists. Smaller and more rugged decoders can be made even smaller if the maximum bit rate and number of modes and auxiliary outputs are reduced, thus executing a smaller subset of this standard.

2.3.7 Ordering Data. When ordering or describing a decoder in this document, the variables listed next must be specified. Typical characteristics are shown where applicable.

2.3.7.1 Input. Input to the decoder is 75-ohm terminated, single-ended with TTL. A data signal and 0° clock are required. In situations where the input signal is received from a data channel (cable, fiber optics, or radio), the TTL voltage presentation and clock recovery are produced by a BSSC or line adaptor card. If the data source is the digital telephone hierarchy, a separate card is used to provide this conversion. Decryption, if required, can take place on either side of the interface card depending on the type of decryptor used and levels on which it operates.

2.3.7.2 Output. The decoder produces video signals and optional data signals on separate outputs.

2.3.7.2.1 Video. The video output is a 75 ohm, 1 V, sync-negative, black-and-white signal unless specified otherwise. The connector type is BNC unless specified otherwise.

2.3.7.2.2 Data. Two types of data outputs may be produced. If the decoder is incapable of decoding data signals present, video outputs will still be produced.

2.3.7.2.2.1 Horizontal Data Lines. Horizontal data lines are optional and are as described in subparagraph 2.1.10.1 through 2.1.10.6. If present in an incoming signal, data lines and a clock/strobe signal are used to transfer the data at TTL levels into external equipment.

2.3.7.2.2.1.1 Number of Lines. The number of lines to be used per field is determined by the encoder. The number is typically between 0 and 10. All data lines must be of the same length. If data-line reception is desired in any given decoder, all outputs can be issued by a single output line with a separate counter to

identify the line number, normally between 241 and 250. If multiple data lines produce multiple outputs, a clock/strobe line would be required for each line.

2.3.7.2.2.1.2 Line Length. Line length for data lines is determined by the encoder used. Maximum length is 1024 bits and the minimum length is one bit.

2.3.7.2.2.1.3 Variable Line Length. If variable line length is desired, the line length is determined dynamically by the encoder and line length transmitted to the decoder. Use of variable line length is not considered common.

2.3.7.2.2.1.4 Data Line Location. Data lines may be transmitted between picture lines within a picture or at the end of the picture page. Decoders equipped to detect such data insertions shall divert the received data packets and received framing and packet length information to external equipment as specified at the time the decoder was manufactured. Operations on such data will depend on the nature of the data, which may include telemetry readings not intended to be part of the picture, timing information, or voice annotation. Decoders not equipped to handle such data insertions shall ignore all such insertions and provide a video output as specified.

2.3.7.2.2.2 Vertical Channel Data. The vertical data signals may be output in serial, parallel, or a specified combination of the two.

2.3.7.2.2.2.1 Time Code Lines. If time code is sent by the encoder (see subparagraph 2.1.9.2.1, note 15), the decoder must provide parallel access to vertical channel bits 61 through 98.

2.3.7.2.2.2.2 Vertical Channel Spares. If vertical channel spares are used, one each in lines 101 through 238 (see subparagraph 2.1.9.2.1, note 18), access to the bits desired in the decoder must be specified.

2.3.7.3 Bit Rate. The maximum operating bit rate must be specified. A 20 Mbits/second rate is a typical maximum for units using TTL, and a 10 Mbits/second rate may be typical for units made with complementary metal oxide semiconductor (CMOS) material. With emitter-coupled logic (ECL), the range goes beyond 100 Mbits/second. The highest bit rate specified will affect power consumption at all speeds. The low end of the operating range is always below 9600 bits/second, theoretically zero. Actual bit rate for a given operation is selected by the user, but guidance on the selection of such rates is given in chapter 4. Use of the highest rate possible for the available channel will always result in the best picture quality and minimize interfacing hardware.

2.3.7.4 Settings. The decoder requires no internal or external changes to receive and decode any picture or data encoded to this protocol. Any given decoder has a maximum bit rate (see paragraph 2.3) and will operate at any rate up to the maximum specified for that unit.

2.3.7.4.1 System Reset Button. If the decoder is receiving data but its internal computer is in a locked-up state, the system reset button will reset the decoder to the power-on state. If no reset button is provided, the power switch may be used.

2.3.7.4.2 Internal Test Mode. A switch may be provided to produce a display from an internal pattern generator for testing some of the decoder functions.

2.3.7.4.3 Pixels Per Line. The number of pixels per line is user defined and may take any number value shown in subparagraph 2.1.17 and is selected by setting vertical data channel bits 14 through 17. Typically, encoders have several choices, related by simple ratio, such as 512, 256, and 128 pixels per line. The decoder automatically responds to the encoder to display the proper number of pixels per line.

2.3.7.4.4 Adaptive Priority. Adaptive priority is determined by the encoder and is automatically determined and interpreted by the decoder (see subparagraph 2.1.18).

2.3.7.4.5 Frame/Field Skipping. The use of skipping and type (fixed or variable) is determined by the encoder settings. The decoder displays the last complete frame or field received until a complete new frame or field is received.

2.3.7.5 Operating Power. Rack-mounted decoders typically operate on 105-140 Vac, 50-440 Hz, or other ac systems such as 100-, 208-, or 220-240 Vac. The dc operation from -24 or -48 Vdc buses can be provided for communication system use. Any type of power system may be specified at the time of ordering. Most of the internal workings of the decoder operate on $\pm$12 or +5 Vdc. Decoders operating at 20 Mbits/ second maximum rate should require no more than 50 W. Systems at 10 Mbits/second should require no more than 25 W for operation exclusive of line-handshaking equipment.

2.3.7.6 Physical Dimensions. Decoders are normally mounted in standard 19-inch racks and are 5 1/4 inches high but can be made smaller if required. Space is available in the rack frame for a line adaptor card or decryptor.

2.3.7.7 Environmental Conditions. Decoders can operate over a temperature range of 0 to 50 °C or higher or as specified. If stated, vibration requirements may include transportation shock protection. Sand and dust protection requirements may be appropriate for some uses.

2.3.7.8 Error Performance. The protocol described in paragraph 2.1 operates perfectly only in an error-free environment. The response of such a system to isolated errors of short duration causes a momentary disruption in the picture. This disruption generally consists of a black or white dash that continues from the point of the error to the right-hand edge of the picture. Errors that occur within the synchronization signals cause larger disruptions. Errors that are long, compared to the bit period, cause outages that require resynchronization. Depending on the type and severity of errors anticipated, requirements for the system to reacquire synchronization within a specific time length (one picture line for short errors, one page for longer errors) are appropriate. If losses caused by data errors are unacceptable, an error correction in the link should be employed. Generally, a bit-error rate of one error per million bits produces a subjectively clean picture at the decoder. Greater detail on the issues involved and the effect of data errors can be found in references 11 and 12. Most transmission errors will result from use of air-to-ground links prior to entering the network. These are hard errors and cannot be removed. A reasonable specification for errors between session levels at the transmitting and receiving ends is $1:10^{-6}$ or less.

2.3.7.9 Repair and Maintenance. Requirements for operating manuals as well as for mechanical and electrical drawings should be made at the time of ordering. Decoders are most easily repaired or diagnosed by board-swapping techniques and diagnostics built into the system software.

2.4 Other Considerations. While the protocol operates as shown in the preceding sections, users should consider the following information.

2.4.1 Duplex Operation. In most cases, duplex operation is not used in video systems because of the one-way nature of most instrumentation, surveillance, and entertainment video signals. If a duplex link is desired for any reason, the encoder and decoder at either end of such a link are independent and may operate at different bit rates with other selectable characteristics.

2.4.2 Encryption Systems. Encryption of the video and optional data signals present on the HORACE protocol can take place at several levels. Encryption or randomization is required at the presentation level if clock information cannot be separately fed at the session level and must be extracted from the presentation-level signal. Either randomization or encryption serve this purpose (see reference 14, appendix D, data randomization).

2.4.2.1 Data Presentation Level. Data packets entering and exiting the HORACE protocol may be encrypted or randomized prior to entry into the data protocol and decoded by a complementary system at the output presentation level. Some type of randomization should be used if long runs of data without transitions are expected. If the entire HORACE multiplex stream is encrypted or randomized as well, the data signals are subjected to a double randomization which does not impair or improve the randomization of the entire signal.

2.4.2.2 Transport Level. If bulk encryption is added to data at the transport level and removed prior to delivery to the receive session, the effect is transparent whether or not randomization or encryption is performed at the presentation level.

2.4.3 Burst Operation. The HORACE protocol is normally intended for continuous transmission of images. In some instances, it may be preferable to transmit a single frame or field (one or two pages) and stop transmitting until another picture is needed. With the HORACE protocol in either frame- or field-skipping mode, the last full field or frame received is displayed until another is received. Then, if transmission ceases, the last picture received will be displayed until the decoder is turned off or reset. When transmitting a single field from a cold start, the transmitter need only remain on long enough for the receiver bit synchronizer to lock synchronization with the incoming data burst or to present a valid clock signal to the line-interface card and to transmit a single picture thereafter. A decoder or vertical synchronization pattern detector at the transmitting end can control the transmitter in these instances. No header or end-of-file markers are required for burst mode. Upon receipt of clock pulses, the decoder looks for and displays the first page received. New pages are displayed when reception of each succeeding page is complete. When clock pulses stop, the last page continues to be displayed.

CHAPTER 3

FEATURES OF THE HORACE VIDEO COMPRESSION STANDARD

3.1 Introduction. The HORACE protocol is implemented as an adaptive system which adjusts gray scale and horizontal resolution on a line-by-line basis to provide the best possible picture without overloading the transmission channel. If the full-scale horizontal resolution is selected correctly, most pictures can be sent with a minimum use of the lower-resolution fallback modes. If a bit rate is fixed for a given system and higher horizontal resolution is desired, the user has the option of sending fewer than all picture fields. The display repeats the most recent picture until the subsequent picture is received. A 1:1 sampling sends every other field providing a motion rate of 30 per second, a bit rate higher than standard motion picture film. Typical encoders can operate with a rate as low as 1:15, which provides a motion rate slightly less than two per second. A second option, called "variable sampling," sends a complete picture any time the transmit buffer is unloaded sufficiently to hold one. Picture content would normally trigger a decrease in horizontal resolution or gray scale. In this case, it triggers a decrease in the picture transmitting rate. The variable frame/ field transmission rate is generally set to operate only in the highest resolution mode, transmitting a new picture anytime the channel can accept another. When either type of picture sub-sampling mode is used, the decoder displays the last picture received until it is replaced during vertical blanking with a new picture.

The HORACE protocol is strictly unidirectional, and no use is made of a return or backhaul path. Two-way circuits using HORACE on both ends are not dependent on one another and need not be at the same data rate. The HORACE protocol may be passed through communications channels in a synchronous or asynchronous manner. The data rate may be anything the use can negotiate, limited by the capacity of the channel, and need not be a fixed rate. The document gives the user some idea of how much resolution in several dimensions can be expected at any given rate. If asyn-chronous transmission is used, packet gaps need not be on word boundaries. A strobe or clock signal must be provided if asyn-chronous transmission is used and may be required for synchronous transmission if randomization is not used to allow reliable clock extraction at the receiving end. If the signal is asynchronous because the user is not alone on the communications channel, the requisite clock or strobe signal is needed in the lower levels in any event. The HORACE protocol contains within its format all

information necessary to operate the session and user levels with options selected at the sending end.

3.2 Coding Method. The HORACE protocol is delta-coded in the horizontal direction only, so no degradation of vertical resolution occurs at any bit rate or adaptation. Similarly, no interframe coding is used because blurring of objects in motion may occur. If blurring is seen on the decoded picture, it is caused by motion blurring on the original signal. A shuttered camera must be used if motion artifacts are unacceptable. Several extensions of the HORACE protocol intended for transmission of color or anaglyphic images may be used if motion rates higher than 60 per second are required.

3.2.1 Higher Spatial Resolution Interleaving. Pixel stagger can be engaged when high-resolution measurement of the space between two objects or the distance between an object and either edge of the screen is critical. When the resolution of the original picture is high enough to warrant it, pixel stagger (also called pixel interleaving) can be employed as described in subparagraph 2.1.14. When line stagger is engaged, the beginning pixel on even-numbered lines in a single field is delayed by half a pixel period on the original encoding and on the display. Objects that are at least two lines tall in any field can be resolved in horizontal position by half a pixel period. As a result, 1800 distinct locations can be created when a 900 pixel-per-line transmission is used. The resolution obtained, even with 256 pixels per line, generally exceeds that obtainable with analog transmission links, analog tape recorders, and many CCD-based cameras. If the original signal is a pixilated image with relatively few pixels per line (for example, 320), pixel stagger may be a disadvantage. Testing the actual camera to be used is advisable. A second type of interleaving delays all pixels in the even field with no delay in the odd field, providing maximum vertical and horizontal resolution on nonmoving or certain slowly moving objects. If pixel stagger will not be used for a specific unit, encoders may be ordered without the feature. Generally, decoders should include this feature whether or not it is used, because decoders often outlive specific projects.

3.2.2 HORACE Digital Output Characteristics. The HORACE signal is a highly compressed version of the original analog video signal. As such, it consists of variable-length words and lines to make best use of the data channel. Long runs of ONEs and ZEROs can result from the compression algorithm, and the distribution of ONEs and ZEROs is not symmetrical in the ensemble or on short runs. As a consequence, bit slippages and lack of low-frequency response can introduce system errors and decrease overall data quality. Consequently, a stable clock frequency is required on those systems in which data dropouts may occur. Randomization or encryption use of the type that will produce

normal transition densities for any data and to remove dc components is advised. Experimentation has shown, however, that operation in an ac-coupled system without randomization is possible.

3.3 Data Transmission. The HORACE protocol allows transmission of data not intended to be part of the picture display in two ways. One or more lines of data may be transmitted between fields of the picture. The number of lines transmitted is fixed at the time the encoder is manufactured. Line length, which can be from 1 to 1024 bits per line, may be fixed or varied depending on the type specified. Loading data on data lines is serial with a strobe/clock stepping in the data serially from an external (user-supplied) buffer. External buffer fullness can be used to modify the number of bits transmitted on any set of lines. When the number of bits per line is allowed to vary, the change in line length transmitted on bits 43 to 52 of the vertical channel pertains to the transmitted page that follows, not the data lines transmitted at the end of that page. (If more than one data line is used, all must be of the same length.) A single data line of 1024 bits and a 60 page/second rate (no field skipping) produce 61,440 bits/second. A 933-bit line under the same conditions can supply a DS-0 data or voice signal (see subparagraph 4.4.2). Multiple lines can be used for multiple audio or higher-quality audio transmissions. Data lines do not degrade picture quality, but if data lines are added and data rates are kept constant, the picture will use fallback compression modes with greater frequency. A decoder not equipped to deal with data lines will ignore them and output a normal picture. A separate data-line-only decoder, which recognizes the data line synchronization code 000000000011101010110, can be built fairly easily as a computer peripheral. If clock and data are fed into such a device, only the data-line length is needed.

3.3.1 Vertical Data Channel. Bit 1 of the format word that follows the horizontal synchronization character is used to produce a data channel that has 1 bit per picture line or 240 bits per page. (Bit 1 in data lines, if present, is not considered to be part of the vertical channel.) Some of the vertical channel bits are constrained or serve various housekeeping channels (see subparagraph 2.1.9.2.1). Others are available to the user for external parallel inputs if specified at the time the encoder is manufactured. Vertical channel bits 61 through 98 are assigned for transmitting time codes; bits 101 through 238 may be used for other data. In normal use, the vertical channel variable bits are latched by the encoder immediately before the start of a page transmission, so the time reported will be at the start of the transmitted picture. When this parallel latch is not specified, the user must supply timing to assure that a parallel word fed to the vertical channel and transmitted serially at a nominal 14,400 bits/second will be valid as decoded. Decoders not equipped to output vertical channel data will ignore such data.

3.3.2 Displayed Picture Data. The HORACE protocol allows transmission of data signals added to the input picture. This transmission is intended to be part of the picture as long as those signals are not wholly or partly located within the vertical or horizontal blanking interval. Vertical edge coding is supported as described in reference 15. Horizontal data codes in picture lines below line 23 are removed by the encoding process and cannot be used for data transmission.

3.4 Data Rate Selection. The user must determine the bit rate and pixels per line when setting up the HORACE encoder. The standard supports pixel-per-line resolutions from 128 to 1800, although not all choices may be present on actual units. This selection is not arbitrary. The decoder will automatically determine from the codes transmitted in the vertical data channel what is being sent and adjust to decode and display it accordingly. If the encoder is to be driven in synchronization with a camera, a computer, or a channel bank, the user also determines the data rate either by selecting any of several internal clock rates available on the encoder or by feeding the encoder an external clock. The user has the choice of engaging pixel stagger (also called horizontal interleaving) and frame/field subsampling.

3.4.1 Representative Data Rates. Because HORACE is adaptive, it strives to present the best picture possible given its encoder settings. To determine the highest rate needed for any combination, assume the eight possible brightness changes allowed are distributed in such a way that entropy coding is at least as good as sending the codes as 3-bit numbers. In a complex picture, the figure for a HORACE-encoded picture is on the order of 2.2 bits per pixel. The bit rate needed for any given horizontal resolution is calculated by taking the 23-bit overhead on each line (12-bit sync, 10-bit format, 1-bit fill terminator) plus three times the number of pixels per line. Multiply the result by 240 (the number of lines transmitted per field) and then multiply that result by 60 (the nominal number of fields per second) (see table 3-1).

TABLE 3-1. BIT RATE REQUIRED FOR FULL-RESOLUTION TRANSMISSION OF TYPICAL IMAGES	
Pixels/Line	**Required Bit Rate**
1800	78,091,200
1280	55,627,200
1024	44,568,000
900	39,211,200
640	27,979,200
512	22,449,600
450	19,771,200
320	14,155,200
256	11,390,400
225	10,051,200
160	7,243,200
128	5,860,200

The HORACE protocol, when operating on a totally black-screen input, produces only one bit per pixel because of entropy coding. "No change" is the most likely value of the "next" pixel and each line starts at black. These pixel values are described in table 3-2.

TABLE 3-2. BIT RATE REQUIRED FOR FULL-RESOLUTION TRANSMISSION OF SIMPLEST IMAGES	
Pixels/Line	**Required Bit Rate**
1800	26,251,200
1280	18,763,200
1024	15,076,800
900	13,291,200
640	9,547,200
512	7,704,000
450	6,811,200
320	4,939,200
256	4,017,600
225	3,571,200
160	2,635,200
128	2,174,200

The values in table 3-2 were calculated for a nominal 60-Hz vertical sweep rate, which allows a tolerance of ±1 percent. A change in the vertical sweep rate will affect the numbers proportionately. A change in the horizontal rate will not have a similar effect, because exactly 240 lines of each field form a page. Finally, as resolution of the system increases, the differences between adjacent pixels in the horizontal direction become smaller. As a result, the higher the resolution, the lower the number of bits required per pixel on any "reasonable" scene.

3.4.2 <u>Fallback Modes And Priorities</u>. When the picture gets too busy to allow full resolution at the given pixel rate, the encoder goes to a more coarse quantization (reducing the number of steps in the gray scale) on a line-by-line basis. The decoder then switches to a two-bit-per-pixel code without entropy, fixing the number of bits per pixel at two. And finally, the decoder goes to a horizontal subsampling that decreases the number of pixels per line by a factor of two. The extra bits available at a rate higher than required or at rates higher than required by the engaged fallback mode are fill bits added to selected lines to make the data rate stay constant. If engaged for all lines at the lowest resolution fallback mode rate (two bits per pixel, horizontal subsampling), the minimum data rates will be the same as those in the first table.

3.4.2.1 <u>Typical Data Values</u>. On any real picture, the required number of bits will be somewhere between the two sets of values, because almost any picture contains areas where there are no contrast changes. Consequently, for a given number of pixels per line, a bit rate between the minimum and maximum values shown in tables 3-1 and 3-2 is the proper choice. System experimentation with the actual input picture will determine what will work most optimally. So a system with a 5.1 mb/s data rate will produce a slightly better picture than will a system with a 5 mb/s rate. The system can be used on whatever rate is available that will cause an acceptable picture, given the setting of the pixels-per-line switch and frame/field subsampling rate, if the latter is used. In systems such as the digital telephone hierarchy, where bit rates are determined and the clock signal supplied by the channel bank, the bit rate used is dictated by the system. When the bit rate is controlled by a source unavailable to the distribution system, a "smart mux" is required to provide the proper interface to the digital network.

3.4.2.2 <u>Temporal Subsampling</u>. With frame and field subsampling, the channel bit rate may be greatly reduced with loss of temporal resolution. Field subsampling is preferred if the input picture has any motion in it. Because the reduced temporal resolution rate allows greater latitude for horizontal resolution, the tradeoff should be considered. Sending alternating fields, reduces the motion rate to 30 per second, which is still higher than motion picture film.

Variable field subsampling may be used when full horizontal resolution is desired, but motion is not a serious concern. When variable subsampling is engaged, a full resolution, entropy-coded picture is sent at the fixed data rate. Then no picture is sent until a complete picture can replace the last one sent in the encoder buffer. The decoder displays the last complete picture received until the next one is received and switches to the next picture during vertical blanking. Because entropy coding is used, the time required to send a picture is a function of the data rate and picture complexity, but should generally be as much as one-third the time necessary to transmit a picture at three bits per pixel. For a 256 pixel/line picture and assuming three bits per pixel, a single field contains (23 + (256 x 3)) x 240 = 189,840 bits. At one bit per pixel, the number is 66,960 bits. At the 56-kb/s rate proposed for the integrated switched digital network (ISDN), pictures could be transmitted at a rate of one every 2 seconds. At the T-1 rate of 1.544 mb/s, about 10 pictures could be transmitted per second, approximating the output of many teleconferencing systems.

3.4.2.3 Maximum Communications Rates. When the channel to be used dictates the bit rate, HORACE can be externally clocked to operate at whatever data rate is available. While references 2 and 3 do not accommodate bit rates higher than about 20 mb/s, systems made to the HORACE standard can operate at much higher rates including the standard T-3 rate of 44.736 mb/s. The signal produced by the HORACE encoder does not produce long runs of ZEROs which can cause trouble in maintaining synchronization. Long runs of ONEs are possible but do not cause a synchronization problem because of the alternating polarity of ONEs in such a system.

With a 44.736 mb/s data rate, horizontal resolutions as great as 1800 pixels per line can be sent, which is about twice the resolution allowed by normal NTSC analog transmission techniques. If pixel stagger is used, a resolution of 3600 points along the horizontal line can be resolved on images two or more lines tall, assuming the equipment generating the picture has sufficient resolution to provide such information. Even at the highest resolutions, a "maximum jump" can be produced between adjacent pixels, thus providing a modulation transfer function of greater than 50 percent at the highest resolution. Images of this type must be recorded in their digital form, since analog or digital recordings of the reconstructed video image will not generally support such resolutions. At the T-3 rate, at least 4 mb/s are available for between-field data transmissions (see subparagraph 2.1.10), and high-quality color or three-dimensional transmissions are also possible.

3.5 Use as Scan Converter. The HORACE encoder can be configured to operate as a scan converter to increase or decrease the number of lines in the original picture to produce 240 picture lines at the output of the decoder if the vertical sweep rate of the input picture is close to 60 Hz. Conversion with equal input and output vertical sweep rates may be accomplished by line repetition or deletion, or by interpolation of a specified number of lines by a user-specified interpolation algorithm. Scan conversion between two different vertical sweep rates in the HORACE encoder can also be provided by use of the variable page skipping mode, in which case the output rate from the decoder is 60 pages per second with new pages displayed as received. In all cases, the conversion is a function of the encoder only, and the input and output of the decoder are identical to normal operation. The resulting picture will in any case be displayable on NTSC equipment.

3.5.1 Line Skipping or Repetition. Scan conversion is accomplished by repeating or deleting input video lines to make a transmitted set of 240 lines, either by selection of a fixed number of output lines for a given number of input lines, or by comparison of two write and read buffers. Conversion of 675 line, 60 Hz inputs, for example, is best accomplished by taking the first, third, and fifth of each group of five input video lines. Since conversion of input systems with greater than 240 lines per picture involves deletion of some lines, some picture detail may be eliminated completely or displaced slightly in space in the process. Conversions which increase the number of lines by repeating some lines will lose no details, but may displace or distort vertical details slightly. Delay introduced in the conversion process, typically 200 μsecond, is never greater than the number of lines stored.

3.5.2 Line Interpolation. A slightly more complex arrangement writes incoming video lines to two or more line buffers and reads out picture information from two or more video lines based on a preset weighting or a weighting based on the position of the output line with respect to its position in the raster produced by the video input. The weighting functions can be linear or nonlinear and can include negative weighting on some lines, if required, for the picture types involved. If interpolation is used, the concept of "delay" is less well-defined, but in any case, no longer than the length of the line buffers, which is, at most, several lines.

NOTE

Vertical resolution of any scan-converted system is always limited to the lower of the two systems. If the vertical sweep rates of the two systems differ and variable page subsampling is used, delays may be on the order of the reciprocal of the lower of the two vertical sweep rates in addition to the delays inherent in the system. Ideally, the system used to produce the original picture should be in the desired output format, since any conversion process cannot improve the original picture and is limited by the worst attributes of both systems. If the additional vertical resolution provided by a high-definition system is necessary, the user should consider the high-definition HORACE modes described in subparagraph 2.1.19.

CHAPTER 4

NETWORK CONSIDERATIONS

4.1 Introduction. Like many other options, the choice of communications bit rate (comm rate) in the HORACE protocol is left to the user. Practical considerations should often guide the selection. The choice of comm rate can greatly simplify dealing with the digitized signal if the user's intent is to interface at any point with the multiplexed telephone hierarchy.[1] When selecting features for a specific purchase of equipment, the user should consider the following paragraphs.

4.2 Communications Rate Hierarchy. The digital telephone multiplex hierarchy used in the United States and many other countries[2] is based on a system starting with 3.5 kHz telephone circuits. At 8000 samples per second, a 7- or 8-digit binary signal is produced providing a 56- or 64-kilobit per second (kb/s) signal.[3] This basic signal is called a DS-0.[4] Twenty-four DS-0s constitute a group,[5] which has an 8 kb/s synchronization and supervisory signal added for a total of 1.544 mb/s, and is given the name DS-1. Four DS-1s are combined to make a supergroup. With the added 136 kb/s synchronization/supervisory circuit, the DS-2 tier is created with a bit rate of 6.312 mb/s.

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[1]Note that a bit rate selection in cases where the user is alone on the data channel (RF link, cable, or fiber) is not completely arbitrary either, but no formal hierarchy exists in most situations. In such situations, nothing prevents the use of standard telephone hierarchy comm rates, but no synchronization signal can be provided by the next tier because none exists.

[2]But not all countries - the Europeans use something different.

[3]If a 56 kb/s signal is produced, an 8 kb/s supervisory signal is added. In either case, each voice circuit produces a 64 kb/s signal.

[4]In telephone terminology, a DS-0 signal goes into a T-0 channel.

[5]This terminology remains from analog telephone multiplexing.

Seven DS-2s and additional synchronization and supervisory overhead are added to create a master group with a bit rate of 44.732 mb/s, forming the DS-3 tier. Still larger DS-4 and DS-5 groups exist but are unimportant with regard to HORACE. Some systems allow such inputs as "1/4 DS-1" (384 kb/s) and "1/2 DS-2," (5.404 mb/s) but use of such rates depends on the capability of the equipment at the next tier.

4.3 Smart Muxes. A device called a smart mux exists that can take one or more digital signals whose bit rates are arbitrary but add up to less than some fraction (possibly 90 percent) of the tier bit rate at which the composite stream will be inserted. The remaining available bits contain information to allow demultiplexing this data into its original form by a companion smart demux at the receiving end. There are several problems with this approach, because various types of smart muxes are proprietary designs. Since the smart mux decreases the bit rate available, a better approach is to employ a standard telephone hierarchy rate for the HORACE box. The picture quality is improved by using the higher bit rate and eliminating the trouble, expense, and reliability concerns associated with the smart mux/demux.

4.4 Communications Rate Selection. The HORACE protocol is a compression system with user-selectable nonrecoverable aspects, so the comm rate must be chosen to allow adequate picture quality for the intended use. In particular, pictures at the selected quality may be of better or far lower quality than entertainment-grade television pictures delivered by commercial networks. The following guide describes the various quality options available at specific comm rates.

4.4.1 DS-0 (56- or 64-kb/s). Pictures in variable skip mode and fixed (maximum) horizontal resolution can be sent about every 3 seconds by using the 256-pixel-per-line horizontal resolution. Each picture is made up of a single field at the input and contains no motion blurring. At higher resolutions such as 512 pixels per line, the transmission time increases less than the resolution because of the higher correlation between adjacent pixels and no overhead increase. The 225-pixel-per-line resolution is almost equal to that obtained by a consumer-type video cassette recorder (VCR). The use of 128 or 160 pixels per line may be adequate for some uses, therefore allowing new pictures to be sent less than 2 seconds apart. These low data rates are usable for teleconferencing and for some types of surveillance.

4.4.2 Two DS-0 (112 or 128 kb/s). The use of two or more DS-0 channels permits sending pictures at a faster rate and higher resolution. The individual DS-0s need not be spaced in the DS-1 frame in any particular order.

4.4.3 Quarter-DS-1 (384 kb/s)[6]: Fixed or variable skipping may be used at this rate and above. Fixed skip at 15:1 provides slightly more than two pictures per second. Variable skip permits use of resolutions beyond 320 pixels per line.

4.4.4 Half-DS-1 (768 kb/s). Fixed or variable skip modes are possible with fixed skip at 15:1 or 7:1.

4.4.5 DS-1 (1.544 mb/s). Fixed or variable skip modes up to 3:1 can be used at this rate.

4.4.6 DS-1C (Half-DS-2) (3.156 mb/s). Fixed or variable skip modes up to 1:1 can be used at this rate. No-skip mode with up to 256 pixels per line may be used, but gray-scale or horizontal resolution fallback will occur on part of the pictures.

4.4.7 DS-2 (6.312 mb/s)[7]: At this rate, full resolution at 512 or 640 pixels per line can be provided with no frame skipping on all but the most complex pictures. Full resolution at 750 or 900 pixels per line can be provided with frame skipping.

4.4.8 DS-A (Two DS-2) (12.624 mb/s). At this rate, full resolution can be provided on most pictures at up to 1280 pixels per line. Megabit levels of data can be multiplexed without serious loss of resolution.

4.4.9 Half-DS-3 (22.366 mb/s)[8]. At this rate, full resolution can be provided on most pictures at up to 1800 pixels per line (maximum resolution). Megabit data handling capacity can be provided with no resolution loss on most pictures.

4.4.10 DS-3 (44.732 mb/s): At this rate, full resolution can be provided at 1800 pixels per line with 450 pixels per line alternating UV color or near full resolution at full RGB transmission with megabit data handling.

4.5 Waveform and Voltages. The customary interchange voltage for the data signal at the DS-1 rate and beyond is ±300 mV, balanced 124 ohms, line-to-line. The data format is an AMI, which means that a logic ZERO (or space) is transmitted as zero

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[6]Some DS-2 multiplexing equipment can handle a data stream of this nature. Check with your telecommunications group to determine whether such a rate can be accommodated.

[7]NTSC picture quality is about 450 pixels per line in the best case; VHS videotape presents about 240 pixels per line. Use of a channel resolution greater than that of the source material causes no harm and may be done for convenience.

[8]This combination is used only with a second half-DS-3.

voltage on both output lines, and a logic ONE (or mark) produces either a +300 mV pulse or a -300 mV pulse with respect to ground with the polarity alternating from one to the next. As a result of this AMI, the net long-term dc component transmitted is zero. An AMI input and output for encoders and decoders can be specified at the time of ordering or may be retrofitted by changing a line card.

4.6 External and Internal Clocks. For a source to be fed into the digital telephone hierarchy, that source must be synchronized in phase and frequency to the next tier into which it will be inserted. The clocking for the source (such as the HORACE box) for normal operation is supplied by the multiplexing equipment as an external clock. If the HORACE source is external to the multiplexer bank and external synchronization is not possible, the HORACE source should be operated on an internal clock 1 percent $\pm$ 0.1 percent[9] slower than the intended rate. "Bit stuffing" to accommodate the rate difference will be provided by the multiplexer. The clock signal supplied by the multiplexer is normally an AMI $\pm$300 mV balanced signal, derived from what would be the "return link" in a two-way system[10] but may be a single-ended TTL signal in some instances.

4.7 Pathological Outputs. On AMI signals fed to multiplexing equipment without a clock, a clock signal is regenerated from the data signal itself. To do so requires data transitions which always occur between ZEROs and ONEs and ONEs and ZEROs and between adjacent ONEs as a consequence of mark alternations. However, such transitions do not occur between adjacent ZEROs. Therefore, some clock regeneration slippage can occur if the transmitted data has a long unbroken string of ZEROs. The HORACE protocol does not emit more than 11 ZEROs in a row on normal pictures, but may produce a longer string of ZEROs if data lines containing such signals are present. The "synchronous idle" character in HORACE is a ONE (see subparagraph 2.1.9.6). Use of a randomizer[11] or encryptor[12] in the path causes the expected distribution of data transitions.

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[9]Operation with external synchronization depends on the equipment at the entry tier being capable of such externally timed operation and adjusting to accommodate the communications rate and phase of the incoming data. Different pieces of equipment vary in their capability to deal with such signals.

[10]Most video systems are operated in a single direction only.

[11]The recommended randomizer is the "standard IRIG data randomizer" described in IRIG document 106-93 (see reference 14).

[12]The standard encryptor used in the presentation layer for the signals described here is of the KUTA class such as the KG-66 or KGV-66 ("Nobleman") type. The KUTA encryptor works in a single direction only (two-wire service) and does not change the comm rate or the order of the data in the presentation.

4.8 Backhaul Path. Most video uses (except teleconferencing) are one-way signals, and a return path is neither desired nor necessary. Consequently, any backhaul channel (RF link, coaxial cable, or fiber optic) is superfluous and may be reassigned in the forward direction. A backhaul of the same bandwidth may be necessary for some modes of encryption, but the return path need not contain any specific data.

4.9 Encryption Issues. An encryptor may be inserted in the data path at any point. When used with a companion decryptor, the effect is transparent. If bulk encryption occurs at another tier, the effect is still transparent, and TEMPEST concerns of crosstalk still apply unless a second encryptor such as KG-81 or KG-66 is used in the video data path itself.

4.10 Fiber-Optic Distribution Hierarchy. A multiplexing hierarchy, based on the nature of fiber-optic transmission systems, differs in several respects from transmission links involving microwave radio or coaxial cable because of the nature of the fiber-optic channel's unique characteristics. Fiber-optic transmission channels using the synchronous optical network [SONET] standards are purely binary in nature, and do not use phase, polarity, or amplitude modulation to increase the number of bits transmitted per channel symbol. In fact, the only valid fiber-optic symbols are ZERO (laser off) and ONE (laser on). As a consequence of this difference, the methods for interleaving lower sections in the hierarchy and separating them at the receiving end are different from those used in radio and coaxial transmission. These differences exist below the session level and should be transparent to the user. Within the SONET hierarchy, as within the radio transmission hierarchy, greatest efficiency is realized when the HORACE encoder is driven by the network clock. HORACE equipment for use with fiber-optic systems is normally specified for 75 ohm TTL inputs and outputs rather than AMI.

CHAPTER 5

PRESENT HARDWARE

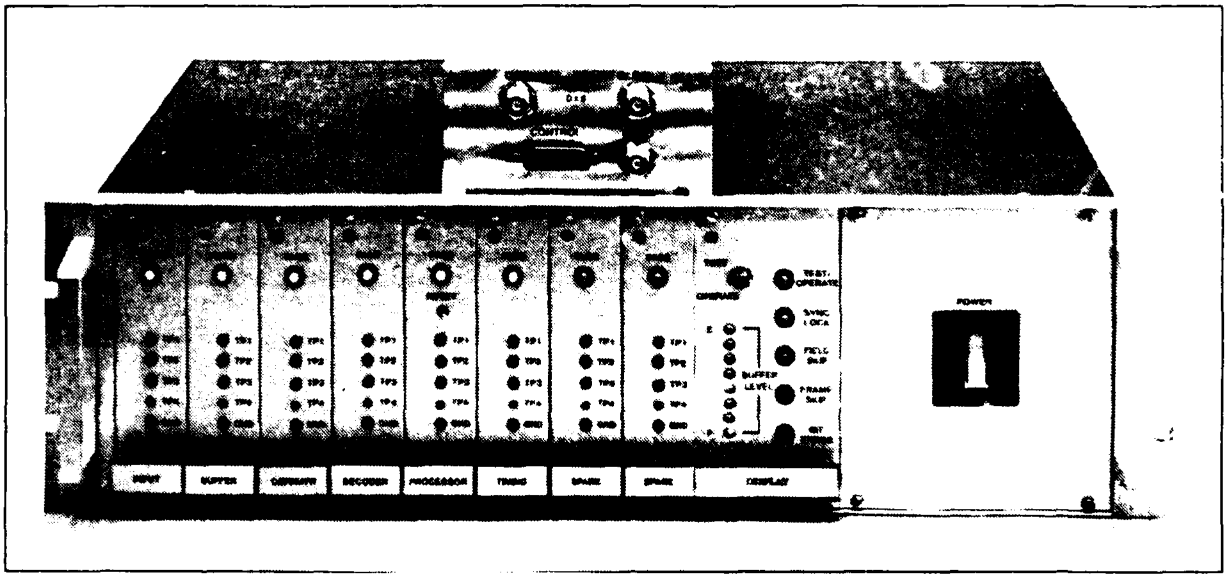

Figure 5-1. Digital video encoder atop digital video decoder.

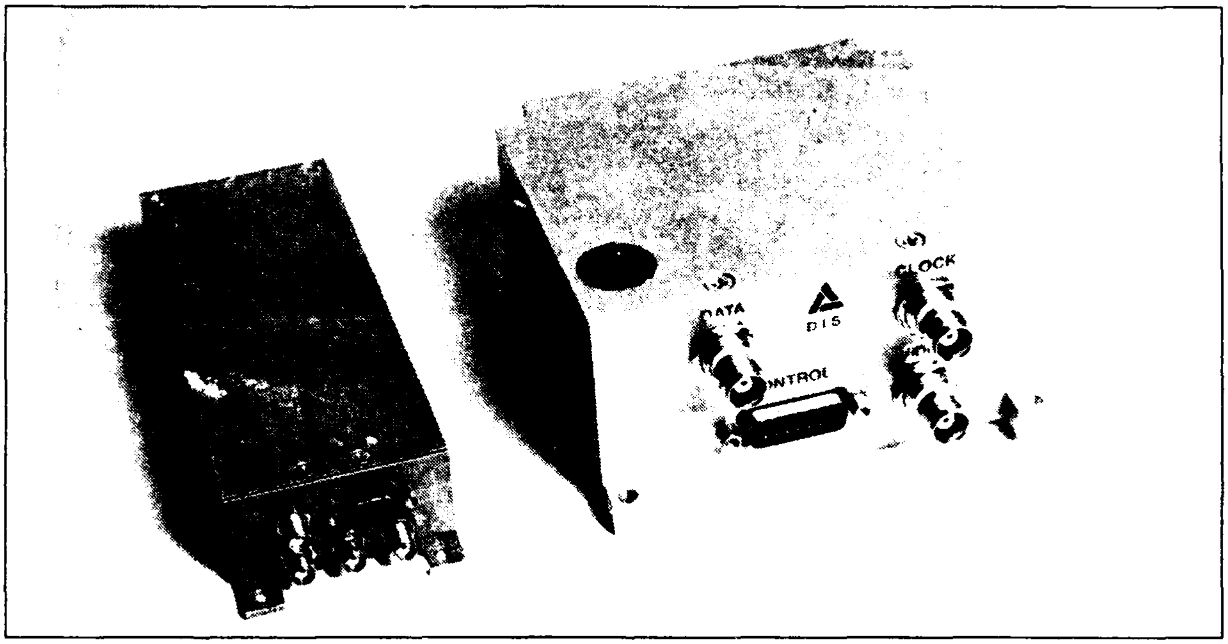

Figure 5-2. Type III digital video encoder (left) and type II digital video encoder (Naval Air Warfare Center Weapons Division China Lake (NAWCWPNS(CL)) specification 2421).

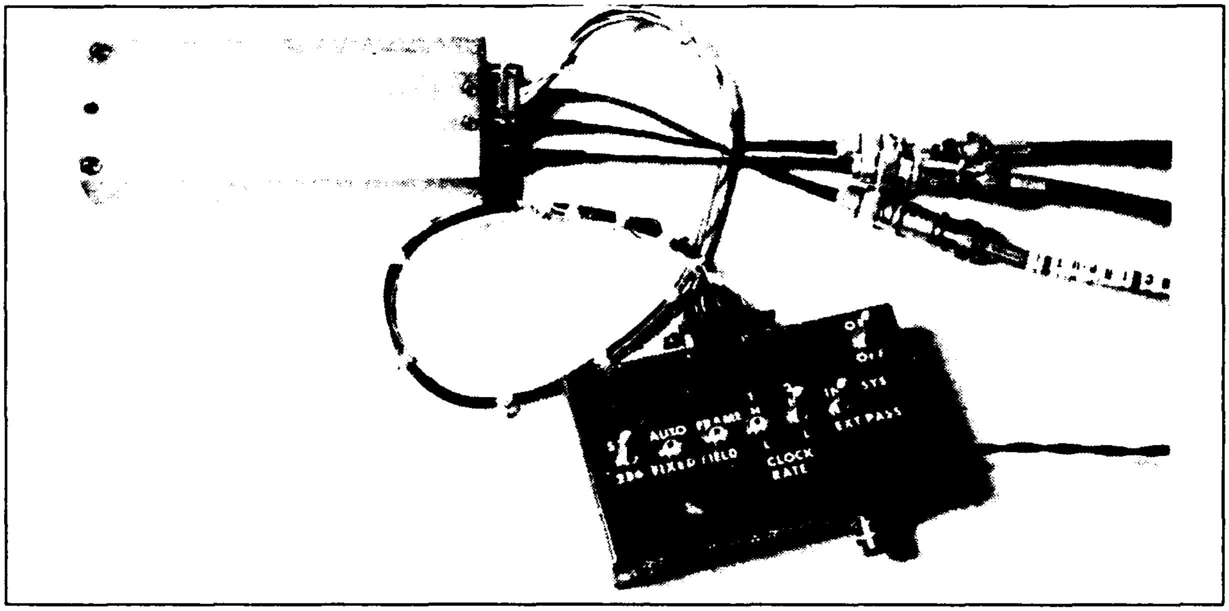

Figure 5-3. Type III digital video encoder with parameter configuration box.

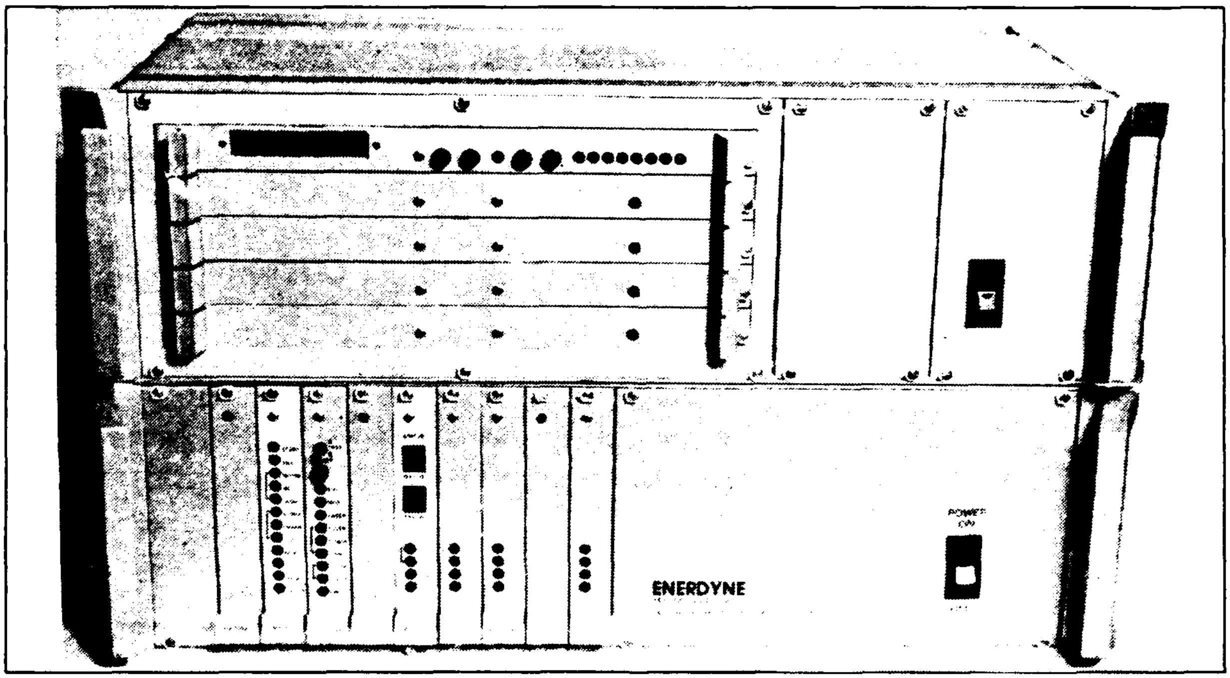

Figure 5-4. Type I color digital video encoder atop color digital video decoder.

CHAPTER 6

EXTENSIONS

While the HORACE protocol provides a signal that is optimum, certain extensions or modifications can be made to optimize the transmitted code for other purposes. Some of these extensions are discussed next.

6.1 Color. Color images contain three black-and-white picture-like signals which, when combined through the appropriate color filters, produce a picture that resembles the color of the original scene with negotiable fidelity (see references 10 and 17). In any real image, the differences between the three color separations are considerably smaller than the differences between three totally different images. The response of the eye is lower to color changes than to changes in brightness and less sensitive to some color changes than to others. It is possible to greatly restrict the color-separation image compared to the black-and-white representation of the scene. In the color version of HORACE, low resolution color-separation signals are transmitted at the end of each line rather than simultaneously with it as in NTSC encoding. The resulting color image is no less acceptable than the image created by NTSC encoding, and may, if derived from and displayed as a three-color signal, be free of some of the artifacts (footprints) that identify an NTSC-multiplexed signal.

6.2 Anaglyphic Images. Anaglyphic images are stereo pairs generated by aiming two synchronized cameras spaced a small distance apart horizontally. They are aimed at the same scene, usually in such a way that objects at "infinity" make identical pictures (see reference 18). As a result, objects that are closer to the cameras appear displaced in the horizontal direction. The displacement increases as the objects get closer; thus, displacement is a measure in the third dimension, and either picture can be used to determine the first two dimensions. Viewing of such an image (if not done electronically) is done with a two-color screen and red-and-blue glasses on two side-by-side monitors with a mirror box generally used to reduce eye strain, or by alternating the views and using glasses with alternating shutters. In the latter case if alternating fields are used, HORACE may be used with no degradation because no interfield coding is used and the pictures are independent. In the case of simultaneous transmission, it should be noted that the difference between the two scenes is small and is the result of horizontal displacement only. Consequently, transmitting the difference in the tail codes permits the entire system resolution to be used on both pictures without significant overhead. It is

anticipated that the standards for anaglyphic separation will be added to the standard if a requirement is identified.

6.3 Calligraphic Images. Images drawn by a continuous line or curve from one point to another rather than "typewriter style" are referred to as calligraphic images. Images of this type are converted into raster-scanned images by drawing them on a screen and photographing the results with a raster-scanned camera. Or they can be drawn into a randomly accessed memory, which is then read as a raster image. Calligraphic images tend to have only a few lines drawn on an otherwise blank screen. Such sparse images are best transmitted in their calligraphic form, which is incompatible with HORACE and the NTSC system.

6.4 Simple Images. Images that consist of a limited number of lines or simple shapes (rectangles, circles) on an otherwise blank background and generated by descriptors are most efficiently transmitted or stored in descriptor form.[1] Simple images that are produced by some external process, but are rendered in descriptor form such as surveillance images, may contain additional data not present in the descriptor form. Consequently, such images are appropriate for transmitting as a compressed NTSC image.

6.5 Binary Images. Television images consisting of only two colors (black and white or red and green) are said to be binary. Such pictures have no gray scale, and one bit is sufficient to represent any pixel. The prime example of a binary image is a computer display. Binary images are not efficiently rendered by the HORACE protocol except when very few objects of one color are present. A different type of encoder and decoder protocol best describes a binary image. If the number of pixels of both colors is near equal, sending on and off bits is most efficient. If one of the colors is far more common, sending change and don't change is preferable with the latter run length coded. Transmission rates well below one bit per pixel are typically attainable. A protocol applicable only to binary image transmission may be made in the future. A simpler encoder will be possible for such transmissions, and the decoder will require a change of one card for binary-only applications.

6.6 Quasi-Static Images. Images that change very little or not at all from frame-to-frame (or in situations where object motion is not the key element for analysis) can be transmitted as frame-to-frame (field-to-field) differences only. In the HORACE protocol, the predictor for any line would then be based, after the first frame, on the difference between the previous pixel and the current pixel from the previous frame. A difference that is

[1]A descriptor is of the form "put a solid red circle of 32 pixels in diameter centered at position (25, 152)."

small if the motion involved only a small part of the picture and zero if the image did not change at all. The HORACE protocol can be used by decreasing the number of pictures sent (skipping) without adding blurring to objects in motion. Operation at a bit rate of 1000 bits/second has been demonstrated in which a field (page) was sent in 2 minutes, 11 seconds. The decoder displays the last field received until a new field is received.

6.7 Segmented Images. Images generated on a blackboard do not change all at once, but gradually as lines, shapes, and lettering are added. When the blackboard is erased, that erasure does not happen instantaneously even though a television picture of the blackboard may show continuous motion. Similarly, radar screens have continually changing images, but the changes taking place occur in only one area on the screen at any given moment. In either case, repeating the entire screen when only some area changes is not a very effective way of optimizing the transmission channel. While extensions can be provided to the HORACE protocol to identify and to change only those areas of the screen where brightness changes are taking place, a more interesting (although less efficient) way is to transmit only those lines in which data have changed. Because a 4- and 64-bit line count are produced in the format codes, a decoder can be produced that responds to this type of addressing. If required, this standard may be modified to include transmission of segmented images.

6.8 Irregularly Shaped Images. Not all images conform to the 4:3 aspect ratio of standard television. Radar images, for example, are round. If only the interesting parts of such a picture are sent, lower resolution can be used at a saving of bit rates on lines that have, for example, only the middle part occupied. However, to do so would require certain deviations from the protocol described here.

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